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PROCEEDINGS

OF THE

Forty-seventh Annual Meeting

Indiana Academy of Science

FOUNDED DECEMBER 29, 1885

VOLUME 41

STANLEY A. CAIN, Editor

Held at Butler University
Indianapolis, Indiana
December 3-5, 1931

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OFFICERS AND COMMITTEES FOR 1931.

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M. W. Lyon, Jr., South Bend.
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Burrage, S.
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Cain, S. A.
Cogshall, W. A.
Coulter, Stanley
Cumings, E. R.
Davis, J. J.
Deam, C. C.
Enders, H. E.
Edington, W. E.
Foley, A. L.
Friesner, R. C.
Hessler, R.
Lyon, Jr., M. W.
Mahin, E. G.
Mees, C. L.
Moenkhaus, W. J.
Mottier, D. M.
Naylor, J. P.
Noyes, W. A.
Ramsey, R. R.
Rettger, L. J.
Wade, F. B.
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Yuncker, T. G.

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E. R. SMITH, DePauw University.
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W. P. MORGAN, Indiana Central College.

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S. R. ESTEN, Department Conservation, Indianapolis.
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B. A. PORTER, Purdue University.

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F. N. WALLACE, State Conservation Commission.
W. N. LOGAN, Indiana University.

Research

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J. H. ARMINGTON, Indianapolis.
H. L. BRUNER, Butler University.
J. E. SWITZER, Indiana University.

Academy Representative on the Council of A.A.A.S.

H. E. ENDERS, Purdue University.

Nominations.

To be announced later.

Junior Academy of Science.

H. E. ENDERS, Purdue University, Chairman.
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FRANK B. WADE, Indianapolis.
O. B. CHRISTY, Ball Teachers College.
L. J. RETTGER, Indiana State Teachers College.

Anniversary Publicity.

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E. G. MAHIN, University of Notre Dame.
M. W. GARDNER, Purdue University.
W. A. COGSHALL, Indiana University.
JOHN S. WRIGHT, Indianapolis.

PAST OFFICERS OF THE INDIANA ACADEMY OF SCIENCE

YEAR	PRESIDENT	SECRETARY	PRESS SECRETARY	TREASURER	EDITOR‡
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1887	*John M. Coulter	Amos W. Butler		O. P. Jenkins	
1888	*J. P. D. John	Amos W. Butler		O. P. Jenkins	
1889	*John C. Branner	Amos W. Butler		O. P. Jenkins	
1890	*T. C. Mendenhall	Amos W. Butler		O. P. Jenkins	
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1892	*J. L. Campbell	Amos W. Butler		C. A. Waldo	
1893	J. C. Arthur	Amos W. Butler		C. A. Waldo	
1894	W. A. Noyes	C. A. Waldo		W. P. Shannon	
1895	Amos W. Butler	John S. Wright		W. P. Shannon	C. A. Waldo
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1898	*C. A. Waldo	John S. Wright	Geo. W. Benton	J. T. Scovell	G. W. Benton
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1904	C. L. Mees	John S. Wright	G. A. Abbott	W. A. McBeth	D. Bodine
1905	John S. Wright	B. McMullen	G. A. Abbott	W. A. McBeth	E. G. Martin
1906	Robert Hessler	B. McMullen	Charles R. Clark	W. A. McBeth	A. L. Foley
1907	D. M. Mottier	B. McMullen	G. A. Abbott	W. A. McBeth	L. B. McMullen
1908	*Glenn Culbertson	J. H. Ransom	G. A. Abbott	W. A. McBeth	H. L. Bruner
1909	A. L. Foley	J. H. Ransom	G. A. Abbott	W. A. McBeth	H. L. Bruner
1910	*P. N. Evans	Geo. W. Benton	J. W. Woodhams	W. H. Moenkhous	L. J. Rettger
1911	*C. R. Dryer	A. J. Bigney	Milo H. Stuart	W. J. Moenkhaus	L. J. Rettger
1912	L. P. Naylor	A. J. Bigney	Milo H. Stuart	W. J. Moenkhaus	C. C. Deam
1913	*Donaldson Bodine	A. J. Bigney	F. B. Wade	W. J. Moenkhaus	H. E. Barnard
1914	Severance Burrage	A. J. Bigney	F. B. Wade	W. A. Cogshall	H. E. Barnard
1915	W. A. Cogshall	A. J. Bigney	F. B. Wade	Wm. M. Blanchard	H. E. Barnard
1916	*A. J. Bigney	H. E. Enders	F. B. Wade	Wm. M. Blanchard	L. F. Bennett
1917	W. J. Moenkhaus	H. E. Enders	F. B. Wade	Wm. M. Blanchard	L. F. Bennett
1918	E. B. Williamson	H. E. Enders	F. B. Wade	Wm. M. Blanchard	L. F. Bennett
†1919	E. B. Williamson	H. E. Enders	F. B. Wade	Wm. M. Blanchard	F. Payne
1920	H. L. Bruner	H. E. Enders	F. B. Wade	Wm. M. Blanchard	F. J. Breeze
1921	Howard E. Enders	Walter N. Hess	F. B. Wade	Wm. M. Blanchard	F. Payne
1922	F. M. Andrews	Walter N. Hess	F. B. Wade	Wm. M. Blanchard	J. J. Davis
1923	Charles A. Behrens	Walter N. Hess	H. F. Dietz	Wm. M. Blanchard	J. J. Davis
1924	C. C. Deam	Flora Anderson	H. F. Dietz	Wm. M. Blanchard	J. J. Davis
1925	E. R. Cumings	Flora Anderson	H. F. Dietz	Wm. M. Blanchard	J. J. Davis
1926	W. M. Blanchard	R. C. Friesner	H. F. Dietz	C. M. Smith	J. J. Davis
1927	Frank B. Wade	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr.	J. J. Davis
1928	E. G. Mahin	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr.	J. J. Davis
1929	Louis J. Rettger	R. C. Friesner	H. F. Dietz	M. W. Lyon, Jr.	S. A. Cain
1930	Rolla R. Ramsey	R. C. Friesner	W. E. Edington	M. W. Lyon, Jr.	S. A. Cain
1931	J. J. Davis	R. C. Friesner	W. E. Edington	M. W. Lyon, Jr.	S. A. Cain
1932	F. Payne	R. C. Friesner	W. E. Edington	M. W. Lyon, Jr.	S. A. Cain

*Deceased. †Officers continued—Annual meeting not held because of influenza epidemic. ‡Listed in Year of Proceedings edited.

[1] The first meeting of the Academy was held Dec. 29, 1885. D. S. Jordan was President for 1885 also.

CONSTITUTION.[1]

ARTICLE I.

SECTION 1. This association shall be called the Indiana Academy of Science.

SECTION 2. The objects of this Academy shall be scientific research and the diffusion of knowledge concerning the various departments of science; to promote intercourse between men engaged in scientific work, especially in Indiana; to assist by investigation and discussion in developing and making known the material, educational and other sources and riches of the State; to arrange and prepare for publication such reports of investigation and discussion as may further the aims and objects of the Academy as set forth in these articles.

WHEREAS, The State has undertaken the publication of such proceedings, the Academy will, upon request of the Governor, or one of the several departments of the State, through the Governor, act through its council as an advisory body in the direction and execution of any investigation within its province as stated. The necessary expenses incurred in the prosecution of such investigation are to be borne by the State; no pecuniary gain is to come to the Academy for its advice or direction of such investigation.

The regular proceedings of the Academy as published by the State shall become a public document.

ARTICLE II.

SECTION 1. Members of this Academy shall be honorary fellows, fellows, non-resident fellows, and active members.

SECTION 2. Any person engaged in any department of scientific work, or in any original research in any department of science, shall be eligible to active membership. Active members may be annual or life members. Annual members may be elected at any meeting of the Academy; they shall sign the constitution, pay an admission fee of two dollars and thereafter an annual fee of one dollar. Any person who shall at one time contribute fifty dollars to the funds of this Academy may be elected a life member of the Academy, free of assessment. Non-resident members may be elected from those who have been active members but who have removed from the State. In any case, a three-fourths vote of the members present shall elect to membership. Applications for membership in any of the foregoing classes shall be referred to a committee on application for membership, who shall consider such application and report to the Academy before the election.

SECTION 3. The members who are actively engaged in scientific work, who have recognized standing as scientific men, and who have been members of the Academy at least one year, may be recommended for nomination for election as fellows by three fellows or members personally acquainted with their work and character. Of members so nominated a number not exceeding five in any one year may, on recommendation of the Executive Committee, be elected as fellows. At the meeting at which this is adopted, the members of the Executive Committee for 1894 and fifteen others shall be elected as fellows, and those now honorary members shall become honorary fellows. Honorary fellows may be elected on account of special prominence in science, on the written recommendation of two members of the Academy. In any case a three-fourths vote of the members present shall elect.

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[1] As printed in Vol. 30, p. 5, 1920-21, with revised paragraphs as indicated in following footnotes.

Nominations for Fellows and Honorary members of the Academy shall be made to the chairman of the Nomination Committee previous to the annual meeting of the Executive Committee. The Nomination Committee shall submit their recommendation to the Executive Committee, which shall then pass the nominees on to the general session of the Academy for final approval.[1]

SECTION 4.[2] The Indiana Academy of Science shall actively promote the organization and operation of local science clubs in connection with secondary schools of the state. Such of these clubs as elect to become members shall constitute the Indiana Junior Academy of Science.

The President shall appoint annually a committee of five members from the Indiana Academy of Science to have full charge, within the Academy, of the Junior Academy of Science. It shall formulate the requirements for membership of local science clubs and election of such clubs must be approved by the Executive Committee of the Academy.

Each applicant club, upon meeting Academy affiliation requirements, payment of an entry fee of $1.00 and an affiliation fee of $1.00 and upon recommendation of the committee in charge, shall receive for its files a certification of membership signed by the President, Secretary, and Treasurer of the Academy. Such affiliation shall continue upon payment of annual affiliation fee so long as the club continues to meet requirements of membership. Each affiliated club will receive one copy of the Proceedings of the Indiana Academy of Science.

The Committee in council with the President, Secretary and Treasurer shall formulate a program of work. An annual report of the progress made shall be presented to the Executive Committee of the Indiana Academy of Science by the chairman of the Academy Committee on Junior Academy of Science.

ARTICLE III.

SECTION 1. The officers of the Academy shall be chosen by ballot at the annual meeting, and shall hold office one year. They shall consist of a President, Vice-President, Secretary, Assistant Secretary, Press Secretary, Editor, and Treasurer, who shall perform the duties usually pertaining to their respective offices and in addition, with the ex-Presidents of the Academy, shall constitute an Executive Committee. The President shall, at each annual meeting, appoint two members to be a committee which shall prepare the programs and have charge of the arrangements for all meetings for one year.

SECTION 2. The annual meeting of the Academy shall be held in the city of Indianapolis within the week following Christmas of each year, unless otherwise ordered by the Executive Committee. There shall also be a summer meeting at such time and place as may be decided upon by the Executive Committee. Other meetings may be called at the discretion of the Executive Committee. The past President, together with the officers and the Executive Committee, shall constitute the Council of the Academy, and represent it in the transaction of any necessary business not especially provided for in this constitution, in the interim between general meetings.

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[1] Amended to present reading Vol. 37, p. 22, 1927-28.

[2] Added at the December, 1931, meeting.

SECTION 3. This constitution may be altered or amended at any annual meeting by a three-fourths majority of the attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

BY-LAWS.

1. On motion, any special department of science shall be assigned to a curator, whose duty it shall be, with the assistance of the other members interested in the same department, to endeavor to advance knowledge in that particular department. Each curator shall report at such time and place as the Academy shall direct. These reports shall include a brief summary of the progress of the department during the year preceding the presentation of the report.
2. The President shall deliver a public address at one of the sessions of the winter meetings of the Academy at the expiration of his term of office.[1]
3. The Press Secretary shall attend to the securing of proper newspaper reports of the meetings and assist the Secretary.
4. No special meeting of the Academy shall be held without a notice of the same having been sent to the address of each member at least fifteen days before such meeting.
5. No bill against the Academy shall be paid without an order signed by the President and countersigned by the Secretary.
6. Members who shall allow their dues to remain unpaid for two years, having been annually notified of their arrearages by the Treasurer, shall have their names stricken from the roll.
7. Ten members shall constitute a quorum for the transaction of business.
8. An Editor shall be elected from year to year. His duties shall be to edit the annual Proceedings. No allowance shall be made to the Editor for clerical assistance on account of any one edition of the Proceedings in excess of fifty ($50.00) dollars, except by special action of the Executive Committee. (Amendment passed December 8, 1917.)

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[1] Amended to present reading Vol. 36, p. 24, 1926-27.

MINUTES OF THE SPRING MEETINGS.

OXFORD, OHIO.
MITCHELL, INDIANA.

The Indiana Academy of Science met in joint session with the Ohio and Kentucky Academies at Miami University, Oxford, Ohio, April 2-4, 1931. Approximately 75 members of the Indiana Academy, not resident in Ohio, were present at the Annual Academy Dinner. Approximately 300 persons were present at this dinner.

A brief business session of the Indiana Academy was called for Saturday morning, April 4th. At this meeting the following business was transacted:

Membership Committee reported the names of 12 applicants for membership. These were elected members of the Academy. The matter of exhibits for the winter meetings of the Academy was discussed. It was decided to have exhibits for these meetings which are to be held at Butler University.

The Academy took action favoring a supplementary spring meeting, time and place to be determined by the Program Committee.

F. M. Andrews, Chairman of the Resolutions Committee, presented the following resolutions, which were adopted by the Academy:

The Indiana Academy of Science desires to express its appreciation for the splendid entertainment accorded it by the Ohio Academy of Science during their joint meeting held at Miami University, Oxford, Ohio, on April 2, 3 and 4, 1931; and to thank the Ohio Academy of Science for their invitation and for the excellent meeting that has been arranged and carried out. The Indiana Academy of Science also extends its thanks to Miami University, its officers, faculty and all others who have spared no efforts to make this joint meeting such a great success.

The meeting was then adjourned.

Supplementary spring meetings of the Indiana Academy of Science were held at Bedford and Spring Mill State Park, May 21-23, 1931. The Executive Committee was called to order by President Davis in the Graystone Hotel, Bedford, at 8:00 p.m. Approximately 50 members of the Academy were present.

Membership Committee recommended ten persons for membership. These were all duly admitted to the Academy.

S. R. Esten, speaking for Chairman H. E. Enders, reported on the activity of the committee in charge of formation of a Junior Academy of Science. It is planned to present the matter to the science teachers of the state at the annual conference of High School Teachers to be held at Indianapolis in October. The matter will then be taken up in a special session during the winter meetings to be held at Butler University in December.

Chairman Pearson of the Program Committee announced the date of the next winter meetings of the Academy, to be December 3-5, 1931, at the Severin Hotel and Butler University, Indianapolis.

C. C. Deam suggested that the next "spring" meeting be held in June or later so that other types of vegetation can be seen. E. R. Cumings called attention to the fact that April is too early and that June is filled with graduations, examinations, etc. President Davis instructed Chairman Pearson to consider the matter, especially with the view of a summer meeting.

President Davis appointed a Resolutions Committee consisting of:

M. W. Lyon, Jr.
L. J. Rettger.
F. M. Andrews.

It was moved by M. W. Lyon, Jr., that telegrams of greetings and sympathy from the Academy be sent to David Starr Jordan, Charles Stoltz, Amos W. Butler and Elwood Montgomery.

Charles C. Deam talked 15 minutes on "Plants of Interest in Monroe, Lawrence and Martin Counties." Will Scott talked 20 minutes on "Animal Life of Donaldson's Cave." E. Y. Guernsey talked 30 minutes of "Historical Lore of Spring Mills."

Lunch was served, Friday, May 22nd, to approximately 125 members and friends, at Spring Mill State Park. The day was spent on trips to Trinity Springs, Purdue Farm, Jug Rock near Shoals, Lost River and through the caves. Dinner was served at the Greystone Hotel, Bedford. This was followed by a social hour.

Saturday was spent on trips through the quarries and stone mills of the Bedford district.

The following resolutions were presented by Chairman Rettger of the Resolutions Committee and adopted by the Academy:

The Indiana Academy of Science is again under great obligations to the Indiana Conservation Commission for being privileged to hold its Spring Meeting in one of the beautiful state parks.

We wish to thank the officers for the innumerable courtesies shown us today which have made our meeting interesting and pleasant.

The members of the Academy desire to say to the officers of the Indiana Conservation Commission that we are not unmindful of the devotion with which they are serving the higher interests of our commonwealth, and that we are watching the gradual unfoldment of their plans for a more beautiful Indiana with pride and satisfaction.

We desire to thank the persons who so ably piloted us today on our trips and whose explanations added much to the enjoyment of the same. We wish also to thank the Program Committee and those associated with them for the local arrangements which have ministered to our comfort during this meeting.

RAY C. FRIESNER, Secretary.

WINTER MEETING.

PROGRAM OF THE FORTY-SEVENTH ANNUAL MEETING OF
THE INDIANA ACADEMY OF SCIENCE
HELD AT
BUTLER UNIVERSITY
INDIANAPOLIS, INDIANA
December 3-5, 1931.

THURSDAY, DECEMBER 3, 1931.

2:30 p. m. Meetings of the Systematic Botanists, Room 131.
7:30 p. m. Meeting of the Executive Committee, Severin Hotel.
8:30 p. m. Motion Pictures of Indiana State Parks. Frank N. Wallace, State Department of Conservation.

FRIDAY, DECEMBER 4, 1931.

8:00 a. m. Registration, First floor, middle section, The Arthur Jordan Memorial Hall.
8:30 a. m. Business Session. Room 131.
9:00 a. m. General Session. Room 131.
Address of Welcome—Dr. Walter Scott Athearn, President of Butler University.
Memorials. Read by title with brief comments by Stanley Coulter.
  Charles W. Stoltz, by Douglas W. Owen.
  Richard B. Moore, by A. R. Middleton.
  William A. Zehring, by Thomas E. Mason.
  †David Starr Jordan, by B. W. Evermann.
  Knute Rockne, by Norman E. Duke.
†The Days of a Naturalist. W. S. Blatchley.
†Mono-Vinyl Acetylene and Other Polymers of Acetylene as Intermediates of a New Practical Synthetic Rubber. J. A. Nieuwland.
10:15 a. m. Demonstrations and Exhibits.
11:00 a. m. Sectional Meetings.
12:30 p. m. Luncheon. University Cafeteria.
2:00 p. m. Sectional Meetings Continued.
3:30 p. m. Tea Served to Members of the Academy and Their Guests.
6:30 p. m. Academy Dinner, Roof Garden, Severin Hotel. Music by Students of the Arthur Jordan Conservatory of Music. *Toastmaster,* Richard Lieber.
8:15 p. m. Address of the Retiring President of the Academy, J. J. Davis ,"Entomology and Entomologists of Indiana."

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† Not published in this Proceedings.

SATURDAY, DECEMBER 5, 1931.

9:45 a.m. Junior Academy of Science. The Inspiration Which the Junior Academy of Science Has Brought to the High School Science Clubs in the State of Illinois. Louis A. Astell.

MEETINGS OF SECTIONS.

BOTANY (Room 131)

T. G. YUNCKER, DEPAUW UNIVERSITY, Chairman.

Read

1. A Simpler Celloidin Process.† Edwin J. Kohl, Purdue University. (Lantern; 10 min.)
2. An Ecological Study of the Bald Cypress in Indiana. Winona H. Welch, DePauw University. (10 min.)
3. Plants New or Rare to Indiana. XVII. Charles C. Deam, Bluffton. (5 min.)
4. Seed Germination and the Survival of Seedlings of *Berberis vulgaris* in Monroe County, Indiana. David M. Mottier, Indiana University. (10 min.)
5. Some Observations on *Pinus virginiana* in Monroe County, Indiana: An ecological Indiana. J. E. Potzger, Indiana University. (10 min.)
6. A Measure of Growth. F. M. Andrews, Indiana University. (8 min.)
7. Plasmolysis. Richard King, University of Maryland. (5 min.)
8. Mixed Cultures of Bacteria and Fungi. C. L. Porter, Purdue University. (Lantern; 10 min.)
9. Why Plant Giants?† R. H. Carr, Purdue University. (Lantern; 10 min.)
10. Survival Studies on Hemlock Seedlings Under Forest Conditions.† Ray C. Friesner, Butler University, and J. E. Potzger, Indiana University. (Lantern, 5 min.) (To be published in Butler University Botanical Studies, 1932.)
11. Anatomical Studies within the Genus Hydrangea. George W. Burkett, DePauw University. (10 min.)
12. Studies on Virgin Hardwood Forests. I. Density and Frequency of the Woody Plants of Donaldson's Woods. Stanley A. Cain, Indiana University. (Lantern; 10 min.)
13. Frost Flowers.† W. N. Clute, Butler University. (Lantern; 5 min.) (To be published in Amer. Botanist, 1932.)
14. Response of Plants to Sawdust. Delzie Demaree, Little Rock, Arkansas. (8 min.)
15. Local and General Distribution of Indiana Trees.† Alva J. Lindsey, Butler University. (Lantern; 10 min.) (To be published in Butler University Botanical Studies. 1932.)

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† Not published in this Proceedings.

16. Method Used in a Statistical Study of a Beech-Maple Association at Turkey Run State Park.† Mabel Marie Esten, Butler University. (Opaque projector; 10 min.) (To be published in Butler University Botanical Studies. 1932.)

17. Chromosome numbers in the Genus Helianthus.† Florence Geisler, Butler University. (10 min.) (Butler University Botanical Studies 2:53-62, 1931.)

18. Chromosome numbers in Quercus and Fagus.† Hellen Aufderheide, Butler University. (10 min.) (Butler University Botanical Studies, 2:45-52. 1931.)

19. An Inexpensive Recording Transpirometer. Raymond E. Girton, Purdue University. (Lantern; 10 min.)

20. Plankton Algae of White River near Indianapolis, Indiana.† C. Mervin Palmer, Butler University. (Lantern; 10 min.) (To be published in Butler University Botanical Studies. 1932.)

21. Succession of Forests as Indicated by Fossil Pollen in Peat Samples from a Northern Michigan Bog.† J. E. Potzger, Indiana University. (6 min.) (Science, 1932.)

22. Preservation of Dry Plant Material. F. M. Andrews, Indiana University. (5 min.)

23. Indiana Taxonomic Notes, 1931.† Ray C. Friesner, Butler University. (5 min.) (To be published in Butler University Botanical Studies. 1932.)

24. The Genus Solidago in Indiana.† Ray C. Friesner, Butler University. (10 min.) (To be published in Butler University Botanical Studies. 1932.)

25. Merrillville Bog: A Statistical Study of the Only Pure Stand of *Pinus strobus* in Indiana.† Alva J. Lindsey, Butler University. (Lantern; 10 min.) (To be published in Butler University Botanical Studies. 1932.)

26. The Algae of Indiana. B. H. Smith, State Teachers College. (5 min.)

27. A Note on *Passiflora lutea* L. Robert Hessler, Indianapolis.

Read by Title.

28. Flowering Plants Previously Unreported for Monroe County, Indiana. J. E. Potzger, Indiana University.

29. Plants of Spring Mill State Park: I, Ferns; II, Trees, Shrubs and Woody Vines. Stanley A. Cain, Indiana University.

By Demonstration (Room 240).

30. Growth Irregularities in Hybrid Freesias Induced by X-rays. W. P. Morgan, Indiana Central College.

31. Visualizing Materia Medica. C. J. Zufall, Purdue.

32. Indiana Aeral Soil Survey. T. M. Bushnell, Purdue.

Exhibits (Room 240).

The following papers have exhibits: 1, 8, 13, 16, 19, 24, 26, 31, 32.

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† Not published in this Proceedings.

CHEMISTRY AND BACTERIOLOGY (Room 127).

E. G. MAHIN, Chairman.

Read.

1. Comparative Studies on Merthiolate with Reference to Laboratory Evaluation and Human Tissue Antisepsis. H. M. Powell and W. A. Jamieson, Indianapolis.

2. Purification of the Virus of Smallpox.† C. A. Behrens and L. B. Morgan, Purdue University. (Lantern.)

3. The Antigenic Proteins of *Salmonella aertrycke*. Frank J. O'Hara, St. Edward's University, and Mary E. Taylor, Texas University.

4. Automatic Alarm Devices for Use in Gas Absorption. Thomas H. Vaughn, University of Notre Dame. (Lantern.)

5. The Double Decomposition Reaction. E. A. Wildman, Earlham College.

Read by Title.

6. Organic Compounds of Selenium—Cycle Diselenides. IV. W. E. Bradt and J. F. Green, State College of Washington.

7. Organic Compounds of Selenium—Cyclic Selenols. V. W. E. Bradt and J. H. Crowell, State College of Washington.

8. Separation of Iron from Indium with Cupperson. F. C. Mathers and C. E. Pritchard.

Exhibits (Room 240).

The following papers have exhibits: 2, 9.

9. Monovinylacetylene and the Synthesis of Practical Rubber.† J. A. Nieuwland, University of Notre Dame. Jour. Amer. Chem. Soc. 53: 4197-4225.

GEOLOGY AND GEOGRAPHY (Room 339).

W. N. LOGAN, Chairman.

Read.

1. Stratigraphic Problems Involved in Determining the Geologic Structure in the Lower Mississippian Outcrop Area of Southern Indiana. Paris B. Stockdale, Ohio State University.

2. The Stratigraphy and Structure of a Devonian Limestone Area in Clark County, Indiana. George I. Whitlatch and John W. Huddle, Indiana University.

3. An Ordovician Fauna from Northwestern University.† R. R. Shrock and H. L. Lloyd, University of Wisconsin.

4. Some Drainage Problems in Southern Indiana.† Gerard Fowke, Madison.

5. Climate and Corn Yield in Indiana, 1887-1930. John K. Rose, Indiana University. (Opaque projector.)

6. Lost River at Wesley Chapel Gulf, Orange County, Indiana. Clyde A. Malott, Indiana University.

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† Not published in this Proceedings.

7. The Underground Features of Sinking Creek, Washington County, Indiana. Robert E. Bates, Indiana University.

8. The Completed Ohio River Project. J. E. Switzer, Indiana University.

9. Experiments in Model-Map Making. A. H. Meyer, Valparaiso University.

10. Notes on the Glacial Boundary in Indiana. W. D. Thornbury, Indiana University.

11. A Fault Along Bryant's Creek, Northern Monroe County. Richard Freed and Ronald Rogers, Indiana University.

12. Mud Stalagmites.† Clyde A. Malott, Indiana University, and Robert R. Shrock, University of Wisconsin.

13. The Principal Beds of Underclay in the Coal Fields of Indiana. George I. Whitlatch, Indiana University.

14. Structural Studies in the Siosi Field. William N. Logan, Indiana University.

Read by Title.

15. Tertiary-Pleistocene of the Navajo Country in Arizona, with a Description of Some of Its Included Fossils.† Albert B. Reagan, Ouray, Utah.

16. A Check List of Caloosahatchie Species. H. I. Tucker and D. Wilson, Greencastle.

17. A list of the Tertiary Species from Acline, Florida. H. I. Tucker and D. Wilson, Greencastle.

Exhibits (Room 236).

The following papers have exhibits or charts: 1, 6, 7, 8, 9, 10, 11, 12.

PHYSICS, MATHEMATICS AND ASTRONOMY (Room 327).

R. B. ABBOTT, Chairman.

Read.

1. An Experiment in Optics, with a New Theory of the Milky Way and of Halos.† Oliver E. Glenn, Vevay.

2. The Genetics of Ideas. R. B. Abbott, Purdue University.

3. The Owen Bridge in Impedence Measurements. J. B. Hershman, Indiana University. (Lantern, charts.)

4. Resonance.† Arthur L. Foley, Indiana University.

5. Some Observations on the Formation of Striae in a Kundt's Tube, and Allied Phenomena. Rolla V. Cook, Indiana University.

6. A Visual Concept of Atomic Structure.† Harvey A. Zinszer, Kansas State College.

7. Derivation of Filter Equations. R. R. Ramsey, Indiana University.

8. Types of Automatism in Nature.† Oliver E. Glenn, Vevay.

9. Further Results of Ionization of Gases by Positive Ions.† Mason E. Hufford, Indiana University. (Lantern.)

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† Not published in this Proceedings.

10. Some Latitude Determinations.† W. A. Cogshall, Indiana University. (Lantern.)

Read by Title.

11. Effects of the Circulation of Insulating Oils Upon Their Dielectric Properties. Jesse C. Hendricks, Clemson College, South Carolina.

12. Radiation and Its Principal Constituents in the Dynamic Universe.† E. A. Smith and F. M. Smith, Secaucus, New Jersey.

13. Cosmosolar Rays.† E. A. Smith and F. M. Smith, Secaucus, New Jersey.

14. An Infinity Pendulum. E. G. Plasterer, Huntington.

By Demonstration (Room 327).

15. Electrodeless Discharge. Charles T. Knipp, University of Illinois.

16. A Demonstration in Diffraction. J. B. Dutcher, Indiana University.

ZOOLOGY (Room 227).

W. P. MORGAN, Chairman.

Read.

1. Insects of Indiana for 1931.† J. J. Davis, Purdue University.

2. The Aid of Places.† Robert Hessler, Indianapolis.

3. Progressive Paralysis of the Nervous System of House Flies. William A. Hiestand, Purdue University.

4. Distribution of Franklin's Ground Squirrel in Indiana.† M. W. Lyon, Jr., South Bend. Amer. Mid. Nat. Jan. 1932.

5. Comparative Erythrocyte Counts of Representative Vertebrates. E. G. Stanley Baker and Loretta E. Kline, DePauw University. (Lantern.)

6. Physiological Assay of Glucosides, Toxins and Poisons on Goldfish. Vincent A. Lapenta, Indianapolis.

7. A Probable Second Record of the Extinct Deer, *Odocileus dolichopsis* (Cope).† William L. Engels, University of Notre Dame. (Lantern.) Amer. Mid. Nat. 13:12-15. 1932.

8. Periodicity in Spawning in *Cumingia tellinoides*.† B. H. Grave, DePauw University.

9. Prehistoric Mastodons of Indiana.† John H. Furbay, Taylor University.

10. The Occurrence of the Fresh-Water Medusa Near Richmond, Indiana. M. R. Garner and M. S. Markle, Earlham College. (Moving pictures.)

11. Revision of and Additions to the List of Spiders of Indiana. F. R. Elliott, Valparaiso University.

12. Winter Birds of Indiana.† Sidney R. Esten, Department of Conservation.

13. Notes on Beaks of Birds.† Frederick H. Test, Purdue University. (Lantern.)

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† Not published in this Proceedings.

14. Birds of Tippecanoe County. II. Louis A. Test and Frederick H. Test, Purdue University.

15. The Amphibia of Montgomery and Putnam Counties.† B. H. Grave, DePauw University.

16. Visible vaso-motor effects in the pulmonary circulation of the frog. W. A. Hiestand.

17. A comparison of the metabolic rates of various insects as determined by carbon dioxide output. W. A. Hiestand, Purdue.

18. The Physiography of the Tippecanoe. Herman P. Wright (Posthumous), Indiana University.

19. Some Modifications of Leg Structures in Hydrophilidae. Russell G. Weber, Butler University.

20. Additional Records of Indiana Butterflies.† Robert W. Montgomery, Stewartsville High School.

21. Records of Indiana Dragonflies. VI, 1931. B. Elwood Montgomery, Purdue University.

By Demonstration (Room 236).

22. Corresponding Stages in the Spermatogenesis of Four Species of Pseudoscorpionida (*Chelanops corticis, C. oblongus, Chelifer muricatus, Chernes scorpioides*).† Henry G. Nester, Butler University.

23. Ichthyophthiriasis Among the Fishes of a Pond in Indianapolis. N. E. Pearson, Butler University.

Exhibits (Room 236).

The following papers have exhibits: 8, 15.

24. The Important Economic Insects Described by Thomas Say.† J. J. Davis, Purdue University.

25. Metacercaria Belonging to the Genus Neascus, Species Probably Vancleavei, which Produced an Epidemic Among the Fishes of Leonard Springs Pond West of Bloomington.† N. E. Pearson, Butler University.

MINUTES OF THE EXECUTIVE COMMITTEE.

The Executive Committee was called to order at 7:30 p. m., December 3, 1931. The following members were present: F. M. Andrews, W. M. Blanchard, W. S. Blatchley, H. L. Bruner, A. W. Butler, C. C. Deam, H. E. Enders, W. E. Edington, A. L. Foley, R. C. Friesner, Robert Hessler, M. W. Lyon, Jr., E. G. Mahin, R. R. Ramsey, F. B. Wade, J. S. Wright, J. J. Davis, T. G. Yunckers, S. A. Cain, E. M. Bruce, N. E. Pearson, W. A. Cogshall, W. J. Moenkhaus, D. M. Mottier.

President Davis made the following introductory remarks: The usual committees were appointed. Dr. M. G. Mellon was appointed to represent the Academy at the dedication of the New Chemistry Building at Indiana University. The President accepted the invitation of the Ohio Academy of Science and gave an illustrated talk on Points of Historic and Scientific Interest in Indiana, at the joint meeting of the Ohio,

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† Not published in this Proceedings.

Kentucky and Indiana Academies at Miami University, Oxford, Ohio, April 2-4. The President also represented the Academy at the Birthday Dinner to Dean Stanley Coulter, given by the Hamilton County Nature Study Club, at Noblesville, and talked on "Coulter the Scientist."

Reports of officers followed:

Academy Foundation.—Chairman Butler presented the following report:

December 1, 1930, balance on hand	$84.85
Total receipts, including interest and other additions	1,329.94
Total	$1,414.79
Investments made, including cost of same	$1,379.08
Balance on hand December 1, 1931	35.71

ASSETS.

Railroad Bldg. and Saving Assoc.—23 shares	$2,300.00
U. S. 4th L. L. Bond E06142095	50.00
Muncie Masonic Temple Preferred	200.00
Standard Oil Company of Indiana, E150525	328.00
U. S. Treasury Notes 1944-54, (H00016648, J00009389, K00028470, A00028471, C00011163)	500.00
Indiana National Bank Savings Account Book 16639	78.32
U. S. Treasury Bonds (A00010851, 23858)	200.00
Same K00029970	500.00
Balance as shown above	35.71
Total assets	$4,192.03

Archaeological Survey.—No report.

Auditing Committee.—Chairman Edington reported that the books of the Treasurer have been examined and found correct on November 30, 1931, by Mr. Frank W. Horan. The audit of the books of the Editor has been postponed on account of the late delivery of the Proceedings and the Reprints. This audit will be made later and reported on at the Spring Meeting. The books of the Trustees of the Academy Foundation have been audited and found correct. The bonds, stocks and certificates have been inspected and found correctly listed.

Biological Survey.—Chairman Lyon reported that work was well under way toward the completion of a bibliography of Indiana fauna and flora. The report carried a recommendation that a sum not to exceed $200.00 be allowed for clerical aid in final compilation of this bibliography. During preparation of material it was stipulated that each title should follow the form of citation used in Biological Abstracts and that it may be followed by such annotations as may seem desirable to the compiler. Professor Paul Weatherwax has charge of the botanical titles, Mr. Sidney Esten has charge of titles dealing with vertebrates and invertebrates other than anthropods and Mr. B. E. Montgomery has charge of titles concerning anthropods. The Committee recommended that the bibliography be published in a taxonomic sequence so that each compiler shall receive due authorship credit.

The committee reiterated its recommendations of a year ago that the policy of the State Conservation Department in securing for future generations important ecological habitats still available within the State, be continued.

The Committee recommended the perpetuation of a majority of its members.

The Committee finally recommends that whereas;

A survey of state educational institutions shows much biological research material inadequately housed, and much valuable material has already been lost to the State by removal of collections to institutions in other states,

Therefore, this Academy recommends that the state universities be urged to provide adequate facilities for the organization and the permanent preservation of specimens of the Indiana fauna and flora.

The report was accepted together with all of its recommendations.

Editor.—Report of the Editor was postponed to the spring meeting of the Academy. Publication of papers read by members of the Indiana Academy at the joint meeting of the Ohio, Indiana, and Kentucky Academies of Science was authorized.

Volume 40 of the Proceedings was off the press in October. This volume contained 402 pages, an increase of 64 pages over Volume 39. In addition to the 100 separates of papers subscribed for by the authors 1,500 bound copies were printed at a cost of $1,806.32 plus $51.58 editorial expenses. The financial report of the editor was delayed until the spring meeting, due to the slowness with which reprint bills were being paid. This delay, with $76.95 still due on Volume 40, is attributed to the general financial conditions.

STATE FUNDS.

Annual appropriation for 1930 Proceedings (1931) vol. 40		$1,500.00
Part cost of vol. 40 to Fort Wayne Printing Co.	$1,291.17	
Part cost of vol. 40 to Stafford Engraving Co.	206.67	
		1,497.84
Reverted to State at close of fiscal year		2.16

REPRINT FUNDS.

Savings account balance from vol. 39	$150.00
Checking account balance from vol. 39 (Irvington State Bank, Indianapolis)	101.90
Arrears from authors vol. 39 (since last report)	9.00
	$260.90
Due on reprints from vol. 39	11.20
Carried over from vol. 39	$272.10
Receivable from authors for reprints, vol. 40	258.95
Received from authors for reprints, vol. 40, to March 17, 1932, balance	182.00
Balance due, vol. 40	$76.95

COST OF VOLUME 40.

State funds, as cited above	$1,497.84
Reprint funds, to complete costs:	
Stafford Engraving Co.	22.49
Fort Wayne Printing Co.	285.99
Editorial expenses:	
By check from Treasurer M. W. Lyon, Jr.	51.58
Total cost of vol. 40	$1,857.90

Cost. vol. 40	$1,857.90	State funds	$1,497.84
Due vol. 39	11.20	Vol. 39 rept.	272.10
Due vol. 40	76.95	Vol. 40 rept.	258.95
Checks 13-20 on vol. 41	12.65	Academy treas.	51.58
Bank balancing service charges	2.00	Interest	4.78*
			$2,085.25
	$1,960.70	Bal. Irv. State bank, Indpls., 3-16-32	123.05*
Cash on hand	1.50		
	$1,962.20		$1,962.20

May 1, 1932 (Signed) STANLEY A. CAIN, Editor.
May 18, 1932 (Signed) W. P. MORGAN, Auditor.

Considering that volume 39 accounts closed with total assets of $272.10 and volume 40 with total assets of $200.00 (to wit: balance, March 16, 1932, of $123.05; due on vol. 40, $76.95;) it is apparent that expenses exceeded the income from the state and the reprint funds by $72.10. This can be considered the extent to which the reprint funds failed to carry the costs of the additional 64 pages over volume 39.

Membership Committee.—Chairman Bruce read the names of 45 applicants for membership in this Academy. These were all accepted.

Press Secretary.—Secretary Edington reported that very few abstracts for publicity purposes reached him. It was suggested that members offering papers on the program submit a carbon copy of their paper to the Press Secretary.

Program Committee.—Chairman Pearson presented the printed program. He explained that the Saturday trip would be made to the Eli Lilly Pharmaceutical Laboratories, Biological Laboratories as stated in Program being a clerical error.

Relation of Academy to State.—Chairman Logan reported that the annual appropriation for publication of Proceedings was expended before the close of the fiscal year.

Research Committee.—Chairman Foley reported progress of the work of the Research Committee.

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* It was necessary to transfer the savings account to the checking account to enable the payment of bills 3-7-32.

REPORT OF TREASURER, INDIANA ACADEMY OF SCIENCE FOR 1931.

Receipts.

Balance on hand January 9, 1931	$639.71	
Collected from members as dues and initiation fees	945.00	
American Association for Advancement of Science	113.50	
		$1,698.21

Disbursements.

Secretary				
Clerical expenses	$16.00			
Stationery and printing (includes stationery for all offices and committees and cost of wrapping Proceedings)	61.30			
Postage (includes postage for mailing Proceedings)	97.18			
Miscellaneous Expenses (includes new addressograph machine)	49.90			
		$223.38		
Treasurer				
Clerical expenses	28.35			
Stationery and printing	22.30			
Postage	27.60			
Miscellaneous expenses	9.51			
		87.76		
Editor				
Miscellaneous expenses	55.58			
		55.58		
Program Committee				
Stationery and printing	111.10			
Postage	99.66			
Miscellaneous expenses	31.57			
		242.33		
Biological Survey Committee				
Multigraphine questionnaire	16.00			
		16.00		
Academy Foundation				
American Association for Advancement of Science funds	113.50			
Additional funds	434.67			
Safe deposit box	5.00			
		553.17		
			$1,178.22	
Balance in bank Dec. 31, 1931			519.99	
				$1,698.21

Respectfully submitted,

M. W. Lyon, Jr., Treasurer.

Examined and found correct, January 30, 1932.

Frank W. Horan, Member Auditing Comm.

REPORTS OF SPECIAL COMMITTEES.

Anniversary Publicity.—Chairman Edington reported that the Chairman of the Committee has done considerable preliminary work with the expectation of assigning specific investigations to the members of the committee. These assignments will be made during the coming year. Accordingly, it is requested that the present committee be continued.

A.A.A.S.—H. E. Enders, Academy Representative of the Council of A.A.A.S. reported progress of work toward bringing the winter meetings of A.A.A.S. to Indianapolis in 1935 or '36.

Brown County Marker.—Chairman Logan reported as follows: "The Committee requests an extension of time for the completion of its report because the route of the Indianapolis-Nashville state highway has not been decided to the Committee's knowledge and further recommendations cannot be made until that location has been determined." The personnel of this committee is W. N. Logan, Chairman, C. A. Malott, B. W. Douglas, E. R. Smith and T. M. Bushnell.

Junior Academy of Science.—Chairman Enders reported concerning plans for the formation of a Junior Academy of Science through the affiliation of High School Science Clubs with the Academy. He recommended the following amendment to the Constitution, to become Section 4 of Article II:

The Indiana Academy of Science shall actively promote the organization and operation of local science clubs in connection with secondary schools of the state. Such of these clubs as elect to become members shall constitute the Indiana Junior Academy of Science.

The President shall appoint annually a committee of five members from the Indiana Academy of Science to have full charge, within the Academy, of the Indiana Junior Academy of Science. It shall formulate the requirements for membership of local science clubs and election of such clubs must be approved by Executive Committee of the Academy.

Each applicant club, upon meeting Academy affiliation requirements, payment of an entry fee of $1.00 and an affiliation fee of $1.00 and upon recommendation of the committee in charge, shall receive for its files a certification of membership signed by the President, Secretary, and Treasurer of the Academy. Such affiliation shall continue upon payment of annual affiliation fee so long as the club continues to meet requirements of membership. Each affiliated club will receive one copy of the Proceedings of the Indiana Academy of Science.

The Committee in council with the President, Secretary and Treasurer shall formulate a program of work. An annual report of the progress made shall be presented to the Executive Committee of the Indiana Academy of Science by the chairman of the Academy Committee on Junior Academy of Science.

The proposed amendment was referred to the General Session for final action.

New Business.—Dr. A. W. Butler presented his resignation as Chairman of Academy Foundation and Trustee of Academy Endowment Funds.

Resignation was accepted with regrets and a rising vote of thanks given Dr. Butler for his 12 years of service on this committee.

Dr. Lyon moved that a committee of three members be appointed to consider the matter of bonding Academy Trustees. This committee to report at next annual meeting in December, 1932. Motion was properly seconded and carried. The following members were appointed: H. L. Bruner, Chairman, W. A. Cogshall, John S. Wright.

The Committee on Publications was requested to present to the next annual meeting a recommendation regarding sale of Proceedings in order to meet requirements regarding publication of new taxonomic descriptions.

President Davis was instructed to appoint a committee to consider the matter of lowering the cost of Life Membership in the Academy, the committee to make recommendations to the Executive Committee at its annual meetings in December, 1932. The following committee was appointed: W. M. Blanchard, Chairman, M. W. Lyon, R. C. Friesner.

The Treasurer was instructed to send out as part of the annual dues notices, a request for statement of special field of scientific interest of each member, such information to be included in the membership list published annually in the Proceedings.

R. R. Ramsey, W. P. Morgan and E. M. Bruce were appointed on a committee to receive invitations for the next winter meetings of the Academy.

MINUTES OF THE GENERAL SESSION.

The minutes of the Executive Committee were read, corrected and approved.

The amendment to the Constitution which was proposed during the meeting of the Executive Committee was again read and unanimously adopted.

The Editor was instructed to publish the Constitution together with all Amendments in Volume 41 of the Proceedings.

The following Resolutions Committee was appointed: F. M. Andrews, Chairman, F. Donaghy and C. E. Behrens.

President Walter S. Athearn of Butler University gave an Address of Welcome after which the regular program of papers followed.

At a brief business session following the annual Academy dinner the following business was transacted:

The Committee on Invitations recommended that the next winter meetings be held at the University of Notre Dame. The recommendation was adopted by the Academy.

Chairman Enders spoke briefly of the Junior Academy of Science and urged as many as possible to assist in the work of organizing the Junior Academy at the meetings to be held on Saturday at Butler University.

Chairman Andrews offered the following resolution which was unanimously adopted:

The Indiana Academy of Science assembled for its Forty-Seventh Annual Meeting at Butler University desires to express its appreciation and thanks to the University, its officers and faculty for the excellent arrangements and plans for our meeting, and those who have provided perfectly for our entertainment. The thanks of the Academy are especially extended to President Athearn for his address of welcome. To all who have contributed so liberally in every way of their time and efforts we again extend our thanks for our very pleasant and successful meeting.

Chairman Rettger of the Committee on Nominations made the following report which was unanimously adopted:

Honorary Fellow, H. C. Oberholzer, Washington, D. C.
Fellows—Nathan E. Pearson, Butler University.
  L. A. Test, Purdue University.
  Allen D. Hole, Earlham College.
  C. E. Deppe, Franklin College.
  B. A. Howlett, Rose Polytechnic Institute.
President, Fernandus Payne, Indiana University.
Vice-President, Richard Lieber, Department of Conservation.
Secretary, Ray C. Friesner, Butler University.
Assistant Secretary, W. P. Morgan, Indiana Central College.
Treasurer, M. W. Lyon, Jr., South Bend.
Editor, S. A. Cain, Indiana University.
Press Secretary, W. E. Edington, DePauw University.

MINUTES OF JUNIOR ACADEMY OF SCIENCE.

Meeting was called to order at Butler University by Chairman Enders at 10 o'clock December 5, 1931.

The meeting was opened with an address upon the nature, functioning and value of the Junior Academy of Science by Mr. Louis Astell. Considerable discussion followed. Mr. Wade discussed the plan followed in promoting science clubs at Shortridge High School. He pointed out that active clubs must always be sponsored by enthusiastic teachers.

Miss Edna Banta discussed the work of the science club in the North Madison High School. She reported upon their scheme of achievement points as an aid in maintenance of enthusiasm.

Mr. Hargraves spoke of the plan used at Arsenal Technical High School. He likewise reported that awards are made for achievement, points being given for such activities as attendance, taking part in program, attendance at field trips, first proven report of a species of bird or flower for the season.

Mr. C. O. Pauley discussed the plan used in the Valparaiso High School. He reported a number of clubs covering all phases of school activities.

Mr. M. M. Williams spoke regarding the work in the Bloomington Junior High School. He reported that club membership is limited to 25 members. Members are encouraged to undertake investigations within the range of high school abilities.

Mr. Ross Stacy spoke of the work at Washington (Indianapolis) High School and Miss Clemie Ransom spoke of the work at Crispus Attucks (Indianapolis) High School.

Two reports were given by high school pupils as illustrations of pupil work in these clubs:

Miss Genevieve O'Hair of Greencastle High School spoke of Nature in the North Woods and Mr. Richard Strain of Bloomington Junior High School gave a talk on habits and behavior of various species of fishes.

The following regulations were adopted for affiliation of high school science clubs with the Indiana Academy of Science:

1. A first class teacher, a member of the Indiana Academy of Science must act as sponsor, and provide inspiration and suggestions to the member club.
2. The club must prepare a constitution modeled after that of the Indiana Academy of Science. A copy of which is to be deposited with the Chairman of the Junior Academy Committee.
3. Apply to Indiana Academy of Science for affiliation—Howard E. Enders, Chairman of Committee on Junior Academies of Science, Purdue University, W. Lafayette, Indiana.
4. Application be accompanied by a copy of the constitution of the applicant club.
5. Entry fee of $1.00 and annual affiliation fee of $1.00 must accompany application for affiliation.
6. Each club must send at least one delegate other than the sponsor to the annual meetings of the Indiana Junior Academy of Science.
7. One or more clubs may become affiliated from each high school.
8. All clubs affiliated before March 1, 1932, will be considered charter members of the Indiana Junior Academy of Science.
9. As many clubs as possible are urged to send exhibitions of their activities for presentation to both the Indiana Academy of Science and the Indiana Junior Academy of Science.
10. The Proceedings of the Indiana Academy of Science will be sent annually to each affiliated club.

Mr. Sidney Esten, member of the Committee on Junior Academy of Science, was appointed as "field" and "contact" man for the Junior Academy of Science.

EXHIBITS.

The following exhibits were offered as illustrations of the activities of these clubs:

The Crawfordsville High School was represented by a collection of mounted Lepidoptera, the work of Mr. William Leavenworth, and by a collection of mounted birds, bird pictures and 47 cases including 150 species and over 300 individuals of mounted Lepidoptera, the latter collections being the work of Mr. Fred Hall.

The Valparaiso High School exhibited a number of ingenious pieces of apparatus constructed by Mr. Joe Urschel, member of the club. Five types of pin-hole cameras were exhibited with examples of pictures taken with each. The first was cylindrical about the size of a large hickory nut taking a picture 11 mm. in diameter with an exposure of one second. The second was an ordinary pin-hole camera taking a four by five inch plate. The third was of a like nature but with a focal length of 5 cm. and with the pin-hole situated high in order that tall buildings might be photographed at very close range. The fourth was a freak-taking camera with the plate set at an angle to the usual position. The fifth takes fifteen small rectangular pictures with one loading of the film on the outside of a cylinder, which is turned after each exposure. This exhibit also included a steam boiler modeled after that invented by Hero, in 120 B. C. and a hygroscopic motor, both constructed by Mr. Urschel.

The North Madison Nature Club exhibited mounted collections of moths, beetles, butterflies and dragonflies together with pictures and notebooks supplementing the collection. The club was represented by Mr. Frazier Hitz.

The Greencastle Nature Club exhibited a collection of photographs illustrating natural history studies in the North Woods. These were the work of Miss Genevieve O'Hair, member of this club.

At the joint meeting of the Chemistry-Physics-Biology sections, at the State Teachers' Association, Professor Enders of Purdue University, spoke in behalf of the proposed Junior Academy of Science. He asked for exhibits, from the science clubs already in existence, these exhibits to be made expressly for the Academy of Science meeting.

This suggestion was presented to the Shortridge Chemistry Club, by the sponsor. A committee was appointed to plan an exhibit. The subject "Salt" was chosen, because it was possible for the club members to make a number of the products exhibited.

Crude salt is shown with four major uses. (1) Refined as table salt; (2) The starting material in the production of hydrochloric acid; (3) As a source of chlorine and sodium hydroxide, by electrolysis of brine; (4) In the preparation of sodium carbonate and sodium bicarbonate by the Solvay process.

The exhibit was prepared by the club as a whole at a regular meeting.

RAY C. FRIESNER, Secretary.

DEAN RICHARD BISHOP MOORE

CINCINNATI, OHIO
May 6, 1871

NEW YORK CITY
January 20, 1931

The death, on January 20, 1931, of Richard Bishop Moore, Dean of Science and head of the Department of Chemistry at Purdue University, removed from the ranks of the Indiana Academy of Science one who at two periods of an illustrious career had been an active and efficient member.

Dean Moore was born at Cincinnati on May 6, 1871, the third child and second son of William Thomas Moore and Mary Bishop Moore. His maternal grandfather, for whom he was named, was mayor of Cincinnati in the days of Lincoln and later governor of Ohio. His immediate ancestors were Kentuckians who were descended from migrating Virginians.

William Thomas Moore was a typical example of the humbly-born middle-westerner of uncommon mental energy. He was born in a log cabin in Henry County, Kentucky, lost his father at the age of eight and from that time had to become a support for his mother and her family. At 18 he had no schooling but had learned to read and knew well Shakspere, the Bible and certain books of history which had come to his hand. His ambition for an education led him to study at night by the light of pine cones for he could not afford candles. Ultimately he managed to secure a college education, became a clergyman of the Christian Church (Disciples of Christ) and rose to a position of leadership in the religious world. He became an ardent advocate of Christian Unity, that is, the union of all the religious sects into one great body. To win the support of British Christians for this worthy cause, he resigned in 1878 the pastorate of the Central Christian Church of Cincinnati and took his family to England. Ultimately Dr. W. T. Moore became pastor of a large church in London and editor of a religious weekly newspaper, the Christian Commonwealth, which exerted a wide influence.

The Moores continued to reside in England until 1895, that is from Richard's eighth to his 25th year. It thus came about that his education was chiefly British. He spent one year, 1885-6, at the Institute Keller in Paris. During his school-boy period he became greatly interested in chemistry and in 1886 entered University College, London, that he might be near the famous Ramsay. Here he spent four years, then taught for a few years in British schools. Returning to the United States in 1895 he became an assistant in chemistry at the University of Chicago, completing the requirements for the B.S. degree in 1896.

In 1897 he went to the University of Missouri as an instructor in chemistry and hither came, in 1902, Herman Schlundt. The two young men quickly formed a friendship and scientific partnership which was destined to be lifelong and of the greatest scientific importance. Work on radioactivity was in its infancy and the young men were eager to repeat experiments such as those of Rutherford and Soddy at McGill University which appeared to indicate with astounding probability that atoms disintegrate and form new elements. They had one ounce of thorium nitrate and they found that it really would act on a photographic plate. That was enough and from that time they spent every moment that could be spared from their long teaching hours and, according to Dr. Schlundt's recollections, several that should not have been, in devising electroscopes and ionization chambers. Hampered as the work was by lack of chemicals and satisfactory apparatus, several important papers were published by the young men. Incidentally they tested the nearby springs and well waters for radio activity.

In 1905 Moore was called to the Chair of Chemistry at Butler College and here he remained until 1911 with the exception of a leave of absence in 1907-8 which he spent in research work with Ramsay at University College. In the summer just preceding this leave he had, with Schlundt, made a survey for radioactive properties of the springs of the Yellowstone National Park in behalf of the U. S. Geological Survey. The object of the government investigation was to find whether the hot springs and geysers were due to localized quantities of radium in the rocks about them. Naturally the result of the investigation failed to support this rather naive idea. However a very pleasant vacation was had by the two young scientists.

During Moore's Sabbatical year with Ramsay he worked upon the separation and purification of krypton and xenon, the least abundant of the rare gases of the atmosphere. By fractionating the heavy residue from 119 tons of liquid aid which had been given by Georges Claude of Paris, some 300 centimeters each of krypton and xenon were obtained in a high state of purity. He determined the physical constants of the two gases and his data still stand in the literature. On his return to Indianapolis he devoted much time to a search for a rare gas, heavier than xenon for which there seemed a place in the periodic table of the elements. Owing to uncertainty as to the number of rare earth elements and the position of these elements in the periodic table, there was at that time no suspicion that radon (radium emanation) was the heaviest member of the inert gases. Many members of the Academy probably have heard Dr. Moore report on this investigation and have seen the complicated and ingenious apparatus which he devised to further the work. All his efforts of course had to be fruitless, but ten years were to elapse before the reason became clear. Meanwhile, he was also continuing his researches on radioactivity and had acquired such reputation in this field that on the opening of the Chemists' Club of New York he was invited to be one of the principal speakers. As a result of the impression he made on this occasion he was invited to the staff of the Bureau of Soils at Washington and resigned his Chair at Butler College to accept this appointment.

It was becoming evident that radium was an important agent for the control or cure of cancer. Its cost at this time was about $120,000 per gram. Most of the carnotite ores of Colorado were being shipped abroad for extraction of their radium content. Moore urged strongly upon responsible government bureau heads the importance of refining the carnotite in this country and the certainty that the cost of radium could thus be very greatly reduced. All the radium produced up to that time constituted a bulk no greater than that of a garden pea. The annual death toll of cancer in the United States alone was in the neighborhood of 75,000. As a result of his urgent pleas Moore was transferred to the Bureau of Mines and put in charge of an experimental bureau at Denver for the investigation of rare minerals. A national radium institute was formed and Drs. Howard Kelley of Baltimore and James Douglas of New York, both interested in the use of radium in hospitals, agreed to contribute $75,000 each for the promotion of radium production and a co-operative arrangement was made for the work to be done by the Bureau of Mines. As a result of improving methods of extraction, 8½ grams of radium element were obtained at a net cost of $345,000. The Great War produced a sudden demand for larger quantities of the rarer metals such as vanadium, molybdenum and tungsten and to the Denver Laboratory was assigned the task of improving processes for obtaining them. As a recognition of the importance of his work for science and its commercial benefit to the State the University of Colorado conferred upon him the Degree of D. Sc. in 1916.

The World War had stimulated search for a non-flammable gas for balloons and dirigibles and the hope of obtaining helium for that purpose was communicated by letter to Dr. Moore by Sir William Ramsay in February, 1915. Apparently the British Admiralty which had enlisted the aid of Sir William Ramsay did not know of the work of Cady and McFarland in 1907 on the natural gas in Kansas which had been found to contain helium in perceptible quantities. In April, 1917, at a meeting of the American Chemical Society in Kansas City, Dr. Moore discussed the occurrence of rare gases in the natural gas of Kansas, announced the interest of the British Admiralty in helium and urged that production in this country was feasible and should be undertaken. In the following month the matter began to be seriously discussed among the government bureaus and ultimately three experimental plants, one under the direct supervision of the Bureau of Mines, were erected in Texas. At the signing of the Armistice the first consignment of 147,000 cubic feet of 93 per cent helium was on the dock for shipment to Europe. Dr. Moore had been placed in charge of this experimental work in Fort Worth in 1918. In 1919 he was transferred to Washington as Chief Chemist of the Bureau of Mines. In this capacity he retained charge of the helium work, organized the Cryogenic Laboratory in Washington and was the civilian member of the Helium Board of the Army and Navy. During the succeeding decade the volume of helium production was steadily increased and the cost as steadily decreased to about 25 cents a cubic foot. Meanwhile explorations conducted by the leading powers disclosed the probability that the United States possessed a monopoly of helium. This at once made apparent Dr. Moore's unusual foresight in urging upon Congress, as he had, the importance of forbidding the export sale of the gas. To him belongs the credit for first clearly visualizing the superiority over hydrogen of this inert gas for lighter-than-air craft; for his energy in convincing the Congress and the Government Bureaus of the importance and feasibility of extracting it from natural gas; and for the technical skill with which he guided the earlier stages of the commercial processes to sure and solid success. It was an extraordinary feat to lower within a few years the cost of production to a figure not excessively greater than that of hydrogen.

After the production of helium was sufficiently standardized, Dr. Moore withdrew from the Bureau of Mines and joined the Dorr Company of New York City as consulting engineer. Later he was appointed General Manager of the company.

In 1926 he was asked to become Head of the Department of Chemistry and Dean of the School of Science at Purdue University, positions which had become vacant through the death of Dr. Percy N. Evans and the retirement of Dean Stanley Coulter. Thus after a lapse of twenty-five years he returned to his old associates in Indiana. During the summer of 1930 evidences of failing health became a cause of concern to his friends. No apparent cause of trouble could be found but his condition rapidly grew worse. In November he went to the Mayo Clinic where his disease was diagnosed as tumor of the brain. He was removed to the Memorial Hospital in New York City that he might be treated with that very radium which he had been instrumental in producing. Before the effect of the treatment could be fully determined, he was stricken by pneumonia and died on January 20.

Dr. Moore was a man of many sides and many attainments. As a scientist he represented a very near approach to the ideal type. He was thoroughly imbued with the spirit of research, of discovering new truths. He did not know what it was to be daunted by lack of tools. Probably his early training in Ramsay's laboratory had taught him how much could be done with limited resources for it is evident that the great Ramsay worked for most of his life under financial handicap. When Dr. Moore was planning to return to Ramsay's laboratory for the sabbatical year 1907-08, Ramsay wrote him: "I should be very glad to see you an inmate of my laboratory; but you will find a much overcrowded building with extemporized appliances. We have a lot of small rooms, convenient enough for fitting up apparatus, though somewhat underground. I think, however, that you might profitably spend some months here, for some of our dodges are not to be learned by reading, but out of hand. I think you would find this place permeated by a spirit of research—under difficulties." These were apparently just the conditions under which Moore was used to working at Butler College where, of course he had no great financial support, and he and Schlundt at Missouri had become accustomed to constructing apparatus out of old scraps. This sort of training had taught him that much could be done with little and no prospect of protracted and excessive labor deterred him from an investigation which he wished to pursue. It is to be remembered that Moore returned to America in 1895, one year before Becquerel discovered radio-activity and three years before the Curies discovered radium. The work in radio-activity which Moore and Schlundt did at the University of Missouri was due to their own initiative and not at all to any influence which Ramsay had exerted on Moore. Dr. S. C. Lind, one of Dr. Moore's most intimate friends, has expressed his belief that in 1907 Moore took with him to Ramsay's laboratory a technique of radio-active measurement which enabled him to give far more than he received in that particular field. Again in the production of radium it required rather uncommon courage to undertake as a commercial proposition the working up of some 200 tons of carnotite ore to produce a gram of radium. The same dauntless pioneering courage was again required to venture a commercial recovery of helium from natural gas, of which it forms at the maximum 1 to 1.5% and to foresee the means by which the cost of its recovery should ultimately be reduced to a reasonable figure.

He combined in a quite unusual way the skill, patience and persistence of the investigator in pure science with the business grasp and foresight of the commercial executive. The investigation on the physical properties of xenon and krypton and many of the papers on radioactivity represent the highest type of pure and presumably financially fruitless research. On the other hand, when research clearly promised enormous benefit to mankind, as in the case of radium, or to the country, as in the case of helium, he was able to combine the unselfishness of the pure scientist with the shrewd and calculating foresight of the business executive. It was undoubtedly this unusual combination which caused him to advance rapidly to the very forefront of his profession and to attain a reputation not only in his own country but in all lands where research is diligently pursued. The esteem in which he was held by his colleagues of the chemical profession was signified when he was awarded the Perkin Medal for the year 1926. This Medal is the most coveted distinction open to American chemists. Before that he had been awarded the Longstreth and the Potts Medals by the Franklin Institute of Philadelphia.

His gift of clear, persuasive argumentation was shown in the organization of both the radium and the helium investigations. Only a very few pioneers of the medical profession had yet become convinced of the therapeutic value of radium. It was a scientific curiosity for which a fabulous price was asked. A very high degree of skill was required to secure the financial co-operation of the medical profession and of the government before large scale production could be considered. The situation with regard to helium was similar in many respects. Lighter-than-air craft had received little attention in this country and the Departments of War and Navy were not actively interested in them. Very clear and far-sighted vision was required to foresee the importance of such craft and, when that had been demonstrated, to convince not only the Departments but also the Congress of the importance of non-flammable gas for lifting them. When the monopoly of helium possessed by the United States became evident, it again required vision and persuasion to convince the Congress of the wisdom of foregoing the large profits from the sale of helium to other countries. Dr. Moore was entitled to the highest praise for the enthusiasm and the skill with which he brought these two great activities to complete and financially successful fruition. It is scarcely too much to stay that the sole credit for the inception of these enterprises belongs to him.

He had an uncommon ability to arouse the highest degree of co-operative emulation in subordinates and to combine their individual efforts into an effective whole. Lind has referred to this as Moore's outstanding qualification. This quality is very evident in the rapid progress of the radium work in Colorado, in the equally rapid increase of efficiency in the processes for separating helium, and in the reorganization of scientific work at Purdue which he accomplished in his four years there. He was a master in the art of imparting enthusiasm to others and in winning their willing and enthusiastic co-operation.

To the members of the Indiana Academy of Science who knew Dr. Moore during his two periods in Indiana, it is unnecessary to recall his genial and friendly disposition, his enthusiasm for the scientific work of colleagues in other fields, his willingness to support any worthy cause and to spare himself no labor in its promotion. Indiana members of the American Chemical Society recall the vast energy and labor which he put into the plans for the National Meeting of the Society in Indianapolis in 1911. That this meeting was long regarded as outstanding among the semi-annual gatherings of the A. C. S. was very largely due to Moore's enthusiasm and unremitted effort.

One of his cherished possessions was a volume of letters to which practically all his professional colleagues in the State contributed upon the occasion of his leaving Butler College to go to the Department of Agriculture. The writer recently had the privilege of looking over this collection of letters. It was interesting to note the variety of personal qualities and talents which the writers had recognized and admired in Professor Moore. As an educator his interests were not confined to chemistry but he was equally interested and conversant with all the varied phases of campus life and activity. It is recorded that during his years at Butler he made a very real contribution to the welfare of the college through his active interest in athletics and his efforts to have athletic matters placed upon a sound and healthy basis. During his few years at Purdue he became increasingly occupied as personal advisor of students and it was evident that he was remarkably successful in winning their confidence and trust. In spite of the incessant demands upon his time he gave himself gladly to these consultations with students.

He had many research plans which he was eager to prosecute, social and outside professional demands were heavy, and it was imperative that the plans for the new chemical laboratory of which the University stood in urgent need, should be completed as rapidly as possible. These plans absorbed much time for laboratories in all parts of the country had to be scrutinized minutely and the excellencies and defects of each carefully weighed. While the details of the new laboratory were taken over, so far as possible, by Dr. M. G. Mellon, there still remained numerous decisions for Dr. Moore's consideration. The amount of detailed work accomplished during these last four years is by no means the least eloquent testimonial to his varied abilities and even more to his uncommon will power and self-control.

He possessed talents and had avocations of which only his more intimate friends were aware. He had a rather marked talent for drawing and painting. Although he had received no more than elementary instruction in the former, he had the artist's eye for form and color and in his few spare hours had picked up some acquaintance with the technique of painting. At various times he produced a fair number of distinctly interesting pictures and studies in oil. While he made no pretence to musicianship, he had a very real comprehension of, and appreciation for, good music and he missed few opportunities to enjoy it. He inherited probably, or at least acquired, a gift of writing very good verse of which a considerable amount was found among his papers. This includes not only amusing jingle written for festive occasions, but also many examples of genuine poetic feeling and command of form.

The untimely passing of Dr. Moore was a loss to the science he so ably represented, for important projects were left which he had hoped to complete. It was keenly felt by Purdue University which had hoped to benefit for many years from his varied experience. It was even more a personal bereavement to the many friends who valued him no less for his scientific achievements yet even more for his genial and friendly personality and his readiness to devote himself unselfishly to the causes of his friends.

Dr. Moore was twice married; in 1902 to Calthea Pemberton who died in 1918, in 1924 to Georgia Dowell of Dallas, Texas, who, with an adopted daughter, survives him.

A. R. MIDDLETON, Purdue University.

RICHARD BISHOP MOORE

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7. Ein Anomales Verhalten in der Radioaktivität einiger Uranverbindungen, Phys. Z., *9*, 81-4 (1908), (with Herman Schlundt).

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KNUTE KENNETH ROCKNE

VOSS, NORWAY
March 4, 1888

BAZAAR, KANSAS
March 31, 1931

The tragic death of Knute K. Rockne in an airplane crash near Bazaar, Kansas, came as a distinct shock to the whole country. The catastrophe left the nation stricken. He was mourned by everyone, especially because of his influence upon the youth of America.

KNUTE KENNETH ROCKNE

He was born in Voss, Norway, March 4, 1888, the son of Lewis Rockne, a carriage maker, and Martha Rockne. When Rockne was five years old, his father came to America to exhibit his craftsmanship at the World's Fair. Later, Rockne, his mother, and his sisters, joined Lewis here, and the family took up their residence in Chicago.

Rockne's education was acquired in the Brentano grammar school in the Logan Square district of Chicago, and the Northwest division High School (now Tuley High School). He worked at various odd jobs when he had the opportunity, the steadiest of which was that of mail dispatcher in the Chicago Postoffice. He already had made up his mind to enter Illinois University when he was persuaded to enter Notre Dame by two of his schoolmates. This he did in 1911, enrolling in the College of Science. He majored in chemistry and was graduated in 1915, magna cum laude, with a B.S. in Pharmacy. Immediately after graduation he accepted a position as instructor in chemistry at Notre Dame. It is said that he would have been an outstanding teacher of chemistry had he remained in that field. Even after he ceased to teach that subject, he continued to read chemistry and displayed remarkable technical knowledge of the field which often surprised those who had considered his academic background tinted a bit to set off his athletic achievements. His marks in college averaged just under ninety-five per cent. In addition to his being instructor in chemistry his duties included the position of assistant football coach.

In 1914 he married Miss Bonnie Skiles of Sandusky, Ohio. Four children were born to them, Bill, Knute Jr., Mary Jean, and Jack. They all survive him.

In 1918 he resigned his post as instructor in chemistry to take over the duties of head football coach. Previously, in 1916, he had been appointed head track coach, a position that he held until he was relieved by John P. Nicholson, the present track coach, in 1926. Not long after he became head football coach, he was given the position of director of athletics at Notre Dame. Recently, he had been in great demand as a luncheon and radio speaker, and he had just been appointed director of sales forces of the Studebaker Corporation of South Bend when he died.

During the Fall of 1929, he suffered thrombosis in his knee, and was confined to bed until late winter when he was sent to Florida to recover. By the beginning of the 1930 football season, he was able personally to direct the team at practice, and his recovery was regarded as complete when he met his death.

He was elected to membership in the Indiana Academy of Science in 1927, and his passing is sincerely regretted by his many friends in that organization. For a while he was also a member of the American Chemical Society.

NORMAN E. DUKE, University of Notre Dame.

CHARLES STOLTZ, M.D.

SOUTH BEND, INDIANA	SOUTH BEND, INDIANA
January 17, 1864	August 3, 1931

Charles Stoltz was born on a farm just outside of South Bend, the son of a German farmer-carpenter. In a group of autobiographical notes which he once prepared, he expressed the belief that his manual dexterity, inherited and acquired from his artisan ancestors, served him well in the pursuit of his profession as a surgeon later in life.

He attended the district school sporadically throughout his youth. At one time he served as an apprentice to one of the pioneer cobblers of South Bend. His medical career started at the age of ten when he assisted in the reduction of a fracture of the hip in one of his playmates. His interest was so evident, that Dr. Brown, the surgeon, more or less took him under his wing to the extent that he frequently drove out on calls with the doctor and served as handyman at many surgical maneuvers of similar type. Dr. Brown also lent him many books on physiology and anatomy which Dr. Stoltz read at what today would be high-school age.

CHARLES STOLTZ, M. D.

At nineteen, he became interested in law and read through Cooley's Blackstone, Walker's American Law, Tidy's Legal Medicine, Greenleaf, on Evidence, and many other books of legal lore. In 1883, and for several years thereafter, he attended Valparaiso College for short periods. From 1884-87, he taught district school and from 1888-89, he taught as principal in the Union Mills High School in LaPorte County. In the year 1889-90, he attended Indiana University, taking a course in Biology in preparation for the study of medicine, and in 1893, graduated from the College of Physicians and Surgeons, of Chicago (now the medical school of the University of Illinois). During the summer vacations of his university and medical school years, he served as a so-called field expert and salesman for the McCormick Harvesting Machine Company. Upon graduation from Medical School, he opened his office in South Bend and from that time until his death, was one of the leaders in medicine and surgery, not only in his own community, but of the northern part of the state as well.

Dr. Stoltz was not only greatly interested in medicine, but in all of the sciences. No better evidence of this is needed than the many friendships which he formed with the members of the Indiana Academy of Science. He had been a fellow of this organization since 1909 and attended every meeting with the few exceptions when his health confined him to his bed. Through his associations at Indiana University and the Academy, he became the life-long friend of David Starr Jordan, and many other prominent men of science. His interest in the dissecting room and surgery brought him in close personal contact and developed friendship with such men in the medical field as Weller VanHook, and John B. Murphy.

While science, both practical and abstract, played a large part in his life, his deepest interest lay in the study and interpretation of Abraham Lincoln, and the history of the Civil War. He took great delight in traveling far afield, alone or with groups of friends, searching out obscure points of Lincoln lore, and of the battles of the Rebellion. He had thus collected a knowledge as well as a library of Lincoln which was only bettered by two or three others in the middle west. His particular interest in this connection was in demonstrating, to his own satisfaction at least, that Lincoln was not the illiterate individual his biographers would lead us to believe. The closing months of his life, despite the handicap of a rapidly descending blindness, and a sluggish and feeble heart, were devoted to the preparation of a masterly paper entitled the "Tragic Career of Mary Todd Lincoln" which was read before the Round Table of South Bend a short time before his death. Partially as a result of this unusual effort, and his insistence on keeping up his practice, his heart gave out quite rapidly, and on the evening of August the 3rd, he suffered an attack from which he died in a few minutes.

His character, sincerity and ability earned for him the love and esteem of his friends, and the respect and admiration of those who might have differed with his staunchly upheld opinions. His memory was phenomenal, particularly in regard to historical facts, and his interest in life and science was maintained intact up to the moment of his death.

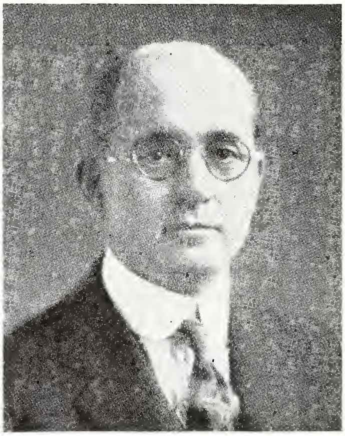
DOUGLAS W. OWEN.

WILLIAM ARTHUR ZEHRING

GERMANTOWN, OHIO	LAFAYETTE, INDIANA
December 6, 1876	May 1, 1931

William Arthur Zehring was born near Germantown, Ohio, on December 6, 1876, and died at Lafayette, Indiana, on May 1, 1931. After the usual elementary and high school courses in his home community he attended Otterbein College from which he was graduated in 1898. He spent the year 1902-03 at Harvard University and received the A. B. degree. Otterbein College conferred the A. M. degree in 1903. He spent several summer quarters at the University of Chicago.

Professor Zehring deliberately chose the profession of teaching as his life work. He taught at Front Royal, Virginia, during the four years 1898-1902, at Campbell College, Holton, Kansas, during the years 1903-05, and at Purdue University during the last twenty-six years. During these years he passed successively through the ranks from Instructor to Professor. He gave himself unreservedly to his work and in later years on many occasions met his classes with a cheerful face when he should have been under medical care. He had high standards of achievement together with great patience and sympathy for the learner. These qualities were apparent to his students. While teaching was his chief concern, he took part in the work of the University outside of the classroom. He served on committees of the Faculty and was chairman of one at the time of his death. He was interested in the Purdue Memorial Union and served as its financial secretary for several years. He had an active part in the business administration of the training camps operated at the University during the war.



WILLIAM ARTHUR ZEHRING

Professor Zehring had a fine sense of responsibility. He was active in church work and served as superintendent and teacher in the Sunday School. He was a member of the Board of Control of the Westminster Foundation for Students of Purdue University, the organization which represents the Synod of Indiana of the Presbyterian Church in its contribution to the moral and religious life of the student body.

Professor Zehring was a good teacher and a good citizen. His best memorial will be the lives of the students who have come under his influence.

THOS. E. MASON.

PRESIDENT'S ADDRESS

ENTOMOLOGISTS AND ENTOMOLOGY IN INDIANA

J. J. DAVIS, Purdue University

An entomologist has been defined as a collector of bugs, but in my remarks this evening may I assure you that I will not include dogs or chambermaids. May I assure you further that an entomologist is more than merely a collector of insects. And may I preface my talk this evening with an explanation for considering a discussion of "Entomologists and Entomology in Indiana" as a suitable one for this body of scientists.

Dr. S. A. Forbes, my first chief and who, by the way, received an honorary doctor's degree from Indiana University, and is one of the greatest entomologists America has ever produced, made the following appropos remarks some 21 years ago in addressing a group of teachers and farmers.[1]

"When, a year and a half ago, entomology was separated from zoology as a department at the University of Illinois, I was asked by one of the college deans if I did not think that it was too limited and subordinate a subject for departmental independence. I replied that entomology was really the larger half of zoology—an answer which was taken as jocular and received with some amusement, but which was intended seriously, and which can be substantially justified from several points of view." This comment made by a man internationally famous as a zoologist and as an entomologist, is well substantiated in the continuing remarks made in the address from which the above introductory statement is quoted.

Insects are important not only to the farmer, as is so often supposed,—they are of importance to builders, to the housewife, and in fact to every citizen regardless of his vocation or position in life. Great calamities may be traced to insects,—as the bubonic plagues, typhus and trench fevers, malaria and yellow fevers. And on the other hand some of the greatest achievements have been possible by subduing insects, as for example the building of the Panama Canal as a direct result of mosquito control, and also by the utilization of insects, as the honeybee for honey production and the pollination of fruit flowers.

I briefly refer to these facts to assure you that the problems confronting the entomologist are great and to emphasize the importance of the subject before us this evening. Indiana entomologists have played no small part in unraveling many of the intricate entomological problems which have confronted us and it is to them we will pay tribute this evening.

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[1] The Insect, The Farmer, The Teacher, The Citizen, and the State. Illinois State Laboratory of Natural History, 1915. Address given at Normal, Illinois, December 13, 1910.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

Insects and insect depredations were doubtless present from the beginning of civilization. Indeed the earliest records in the Bible and early Egyptian writings tell us of insect abundance and insect problems. The same statement is doubtless true for the area now including Indiana. While we have found no reference to insects in earliest Indiana records for Indiana, we do know that the Indians held numerous superstitions about insects and these doubtless applied to Indiana as well as other sections of North America. We also know that insects damaged the crops of the early North American Indians and that several kinds of insects were commonly used by the Indians for food.

Our earliest published Indiana insect records are to be found in a collection of statements published by the Indiana Historical Commission in 1916, under the title "Indiana as Seen by Early Travelers."[2] In this publication David Thomas, a pomologist of note, referred frequently to insects. Under date of June 30, 1816, he advises that in some taverns sleep was almost impossible because of bedbugs (p. 43), these pests probably having been brought in with the settlers. Crops were also subject to insect attacks, according to Thomas, for on July 7, 1816, he reports (p. 76) destruction of timothy and corn by army worms in the vicinity of Shakertown, some 18 miles above Vincennes. It is interesting to note that the method then used for the control of the army worm is even today used in some localities. Thomas described the control as follows: "Some fields and meadows have been saved by deep furrows, in which logs were constantly drawn by horses, so long as their devourers continued to approach. In this manner thousands upon thousands have been destroyed." Again, referring to conditions in the general vicinity of Vincennes, Thomas states (p. 114, 1818) that the army worm is a periodical pest and that the cutworm and "the caterpillar" are annual pests but the weevil, probably referring to the grain weevil, is unknown. Thomas Jefferson was of the opinion that the honeybee was not a native of North America and to help answer the question Thomas (p. 114, June 16, 1818) quotes from correspondents in Indiana. From these reports it would appear that the honeybee, although common in the woods in 1818, was not observed prior to about 1795, the Indians calling them "white peoples' flies," indicating that the Indians did not observe them until after the advent of the white settlers.

That mechanical insect control devices were employed by early settlers of Indiana, is shown from the following statement made by Thomas (p. 79, July 8, 1816): "At Vincennes I observed a curious fly-flapper. The construction is simple, and in hot weather the fresh air that attends its motion, is scarcely less agreeable than relief from these troublesome insects. Its position is over the centre of the table.

"Two strips of lath three feet long, with a hole in the lower end of each to receive a gudgeon, are first prepared. A broad board with gudgeon so placed in each end, that one edge shall always preponderate, is then connected with the strips. To that edge a piece of linen one foot wide is fastened; and a handle, eighteen inches long, projects from the opposite edge. The upper ends of the laths are then nailed at the ceiling, and a small cord attached to the handle communicates motion to the instrument.

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[2] Lindley, Harlow. Indiana as Seen by Early Travelers, Indiana Historical Commission. 1916.

"A joint in the laths near the ceiling would afford the convenience of elevating or removing it at pleasure."

In his "Journal of a Tour to Fort Wayne and the Adjacent Country, in the Year 1821,"[3] Teas refers to annoying pests as follows:

"Myriads of fleas" prevented sleep and during the day the "musquitoes and gnats are as numerous here as along the sea shore and are very troublesome." (p. 246, July 10, 1821, 30 miles north of Richmond on the Mississinewa River.) Again on page 252, writing from the vicinity of Fort Wayne, July 14, Teas refers to the mosquitoes as very annoying pests.

Writing from New Harmony, September 27, 1825, William Pelham[4] refers to the annoyances of mosquitoes.

William Cobbett[5] relating his experiences in his travels through Indiana in 1828, writes as follows from near Princeton: "Our horses were very much tormented with flies, some as large as the English horsefly and some as large as the wasp; these flies infest the prairies that are unimproved about three months in the year, but go away altogether as soon as cultivation begins."

Scattered through such publications as the reports of the Indiana State Board of Agriculture, beginning with the very first volume in 1851, we find references to the destructiveness of such insects as horse bots, cutworms, wireworms, chinch bugs, white grubs, Hessian fly, grain weevil and others. In the report of 1879, it is interesting to note an extensive article by Harvey W. Wiley, on "The Relation of Science to Agriculture", in which he refers to the insect problems in the following words:

"One of the numerous difficulties which adds to the burdens of the agriculturist is the fight which he is constantly compelled to carry on against injurious insects. Almost every year he is compelled to engage in an unequal contest with the potato bug, the fly, the weavil, the caterpillar and the borers of his fruit trees, while at intervals the locust, the army worm and the grasshopper pour over his fields with resistless power. It is the province of the entomologists to study the habits and methods of reproduction of these injurious insects and to provide some way to arrest their almost marvelous fertility."

"Much has already been accomplished in this direction, but much more remains to be done. It is evident that it is useless for a farmer to fight potato bugs in his field while they are left to increase unmolested in the field of his neighbor. Action against insects must be concerted and intelligent to be effective. Bushwhacking and guerilla warfare can never accomplish anything more than a local result. The campaign to be effective must be regular, with full equipments and a perfect knowledge of the ground to be fought over and the number and disposition of the forces of the enemy."

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[3] *loc. cit.* p. 246.

[4] *loc. cit.* p. 384.

[5] *loc. cit.* p. 511.

"The farmer looks to the entomologist to direct him in the campaign and furnish him all needful information."

"With such scientific aid he should not despair of eventually freeing his fields of these insignificant but destructive pests which now cause him so much loss and trouble."

Beginning with the 1885 report, and coincident with the coming of F. M. Webster to Indiana as an agent of the U. S. Department of Agriculture and collaborator with Purdue University, we find more frequent and well illustrated discussions of the insect problems confronting the farmer.

The above comments are given as a matter of interest and record of early insect problems.

We might well entitle this talk a "Century of Entomology in Indiana", for if we investigated the history of insect research in Indiana, we find it began only a few years more than a hundred years ago when Thomas Say, the Father of American Entomology, came to Indiana in 1826, to continue his entomological studies. Even with this early beginning we did not, until recent years, make the apparent progress of our sister states, Illinois and Ohio. Probably this was due to the fact that our state institutions did not have departments of entomology. Indiana University has never had a separate Department of Entomology and Purdue University did not have such a department until 1912, although some entomology was taught at both institutions in the early 80's.

And yet, if one reviews the development and achievements of entomology in Indiana they at once realize that an unusually high percentage of Indiana Entomologists have attained a national or even an international reputation. Few states can boast of a Thomas Say, a Blatchley, a Webster or a Williamson. In the brief time at our disposal this evening we can only briefly discuss the entomoligsts who have labored within our borders and the achievements they have attained.

Thomas Say. Back of the house known as the William Maclure home, in the historic town of New Harmony, is the tomb of Thomas Say and over it the simple but impressive monument erected in memory of Say by Alexander Maclure, at the request of his brother, William Maclure, in 1845, (fig. 1). On one side of the monument is the following inscription:

Thomas Say
The Naturalist
Born in Philadelphia
July 27, 1787
Died at New Harmony
October 10, 1834

On another surface of the monument we read:

Votary of Nature even from a child
He sought her presence in the trackless wild,
To him the shell, the insect and the flower,
Were bright and cherished emblems of her power.
In her he saw a spirit all divine
And worship'd like a pilgrim at her shrine.

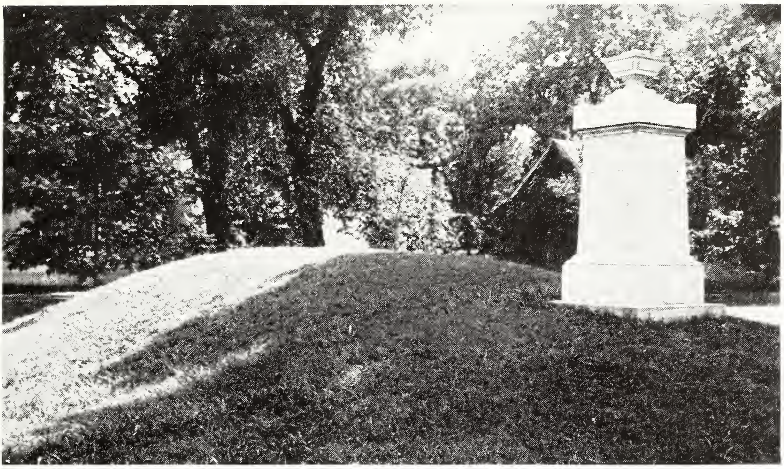

Fig. 1. Tomb and monument over the grave of Thomas Say at New Harmony, Indiana.

Thomas Say, (fig. 2) was doubtless the first student of Indiana insects. In 1826, at the age of 39, Say arrived at New Harmony with a group of scientists known as "The Boatload of Knowledge". Already recognized as a scientific authority, and as one of the founders of the Academy of Natural Science of Philadelphia in 1812, Say later became known as the "Father of American Entomology". Previous to coming to Indiana for residence, he was connected with a number of important scientific expeditions. Say died at New Harmony in 1834, at the age

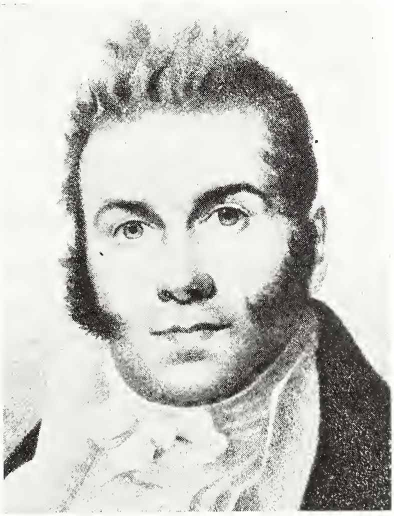

Fig. 2. Thomas Say, 1787-1834. Photograph loaned by Mrs. Nora Fretageot.

of 47 and although a resident of Indiana for less than nine years, it was during this period of his life that the major part of this work was accomplished.

I find several interesting notes touching on the life of Say at New Harmony in "Indiana as Seen by Early Travelers." For example, Earl Bernhard writes, "This gentleman (Say) appeared quite comical in the costume of the society, before described, with his hands full of hard lumps and blisters, occasioned by the unusual labour he was obliged to undertake in the garden."[6] In the same volume V. C. Duclos writes that Mr. Lesueur "and Thomas Say spent most of their leisure in the woods or in the rivers searching for shells and catching fish which they painted and described. * * * Mr. Thomas Say was a fine gentleman and the scholars thought a great deal of him, in fact he was beloved by the whole community. I spent a part of almost every day at his home on the northwest corner of Granary and West Streets".[7] That Say must have had an appreciable sense of humor might be inferred from the fact that he very appropriately described a new species of mosquito under the name *Culex damnosus.*

Say was a taxonomist, as were most of the early entomologists, and he described considerably more than 1,000 new species of beetles and over 400 insects of other orders, including species in every important insect order. A hasty check of his writings shows 404 new species definitely listed from Indiana, including eight orders, as follows: 205 Hymenoptera, 111 Diptera, 17 Coleoptera, 38 Hemiptera, 11 Homoptera, 1 Neuroptera, 5 Ephemerida and 16 Odonata. Many of the species described by Say are major economic species. Checking over one of the recent economic entomology books we find that not less than 10 per cent of the 250 most important insect pests in America, were described by Say. A few of the common economic species are as follows: common wire-worm (*Melanotus fissilis*), thief ant (*Solenopsis molesta*), northern corn root worm (*Diabrotica longicornis*), chinch bug (*Blissus leucopterus*), false wireworms (*Eleodes opaca* and *E. suturalis*), Hessian fly (*Phytophaga destructor*), wheat strawworm (*Dolerus arvensis*), Colorado potato beetle (*Leptinotarsa decimlineata*), potato stalk borer (*Trichobaris trinotata*), striped sweet potato beetle (*Cassida bivittata*), imbricated snout beetle (*Epicaerus imbricatus*), apple flea weevil (*Orchestes pallicornis*), apple curculio (*Anthonomus quadrigibbus*), peach tree borer (*Aegeria exitiosa*), grape leafhopper (*Erythroneura comes*), strawberry weevil (*Anthonomus signatus*), poplar borer (*Saperda calcarata*), rhubarb curculio (*Lixus concavus*), common bean weevil (*Mylabris obtectus*), hickory bark beetle (*Scolytus quadrispinosus*), malarial mosquitoes (*Anopheles quadrimaculatus* and *A. punctipennis*), the common house mosquito of the tropics and important carrier of elephantiasis (*Culex quinquefasciatus*), the two-striped grasshopper (*Melanoplus bivittatus*), pale striped flea beetle (*Systena taeniata*), many important insect parasites, such as *Apanteles congregatus*, and the important Texas fever tick (*Margaropus annulatus*).

Although we honor Say because of his remarkable achievements in entomology, he is also recognized as one of the greatest zoologists and naturalists. He described a large proportion of our common shells, as well as many crustaceans, birds, mammals, reptiles and a certain number of fossils.

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[6] *loc. cit.* p. 426.

[7] *loc. cit.* pp. 546-47.

W. S. Blatchley. One who can be spoken of as the first "Hoosier" entomologist is W. S. Blatchley (fig. 3), a charter member and former president of the Indiana Academy of Science, still alive and entomologically active at the age of 72. Although born in Connecticut in 1859 he was brought to Indiana by his parents when only one year old and has maintained his residence to our State ever since.

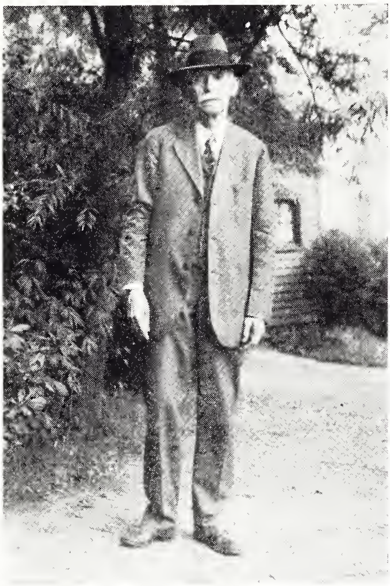

Fig. 3. W. S. Blatchley. (Photo by Wm. T. Davis, Sept. 1929).

Blatchley entered Indiana University in 1883 and received his A. B. degree in 1887, his A. M. in 1891 and was honored by his Alma Mater in 1921 with the LL. D. degree.

His first publication appeared in 1885, when he was 26 years of age, and since then has published 200 titles, 80 on entomological subjects, the remaining 120 on a variety of subjects, including geology, birds, reptiles, batrachians and plants. Included in his papers are descriptions of 14 new genera and subgenera and 470 new species and varieties in the orders Coleoptera, Orthoptera and Heteroptera. For 16 years Blatchley was State Geologist of Indiana, during which time he continued his entomological studies and in his reports will be found many of his papers. He was a close friend of James Whitcomb Riley and I recall a story related about Riley by Blatchley. One day, when Blatchley was State Geologist and had his office in the State Capitol, Riley came in and asked him if "whirligig" beetles possessed wings for flight. Blatchley proceeded to dissect a specimen and reported that the flight wings were aborted and therefor it was apparent they could not fly. To this Riley replied, "Well, I'll have to change a poem I have written because I had them flying." "Ever since a little experience several years ago," continued Riley, "I've been careful about my Natural History. After writing my poem 'When the Frost is on the Pumpkin' - - - I was approached by a farmer lad and asked if I ever lived on the farm and replying in the negative the boy said: 'Well I didn't think so, because you know in your poem you say:

> When the frost is on the punkin and the fodder's in
>   the shock,
> And you hear the kyouck and gobble of the struttin'
>   turkey cock—

"'Well,' said the boy, 'it's only the turkey cock that gobbles, the turkey hen kyoucks.' Since that time I've always been careful of my natural history."

Blatchley is a taxonomist and especially a taxonomist who has presented his studies in monographic form and in a language understandable to the average entomologist and even to the high school student. This, in my opinion, was his greatest achievement. He was a collector, for which I can personally vouch. He was a humorist and to verify this point I will quote the opening paragraphs from one of his popular nature books, "A Nature Wooing at Ormond by the Sea", as follows:

"March 3, 1899—This morning I leave Louisville, Kentucky, southward bound, seeking, as did Ponce de Leon, renewed health and vigor in the 'Land of Flowers.' A heavy mist at first veils everything from view. Occasionally it lifts for a few rods back from the railway, and I see a clump of Kentucky coffee trees, *Gymnocladus dioica* L., still bearing their last year's crop of thick, chocolate brown pods; or, perchance, the curly head and ebony face of a smiling pickaninny gleams for an instant through the mist, which quickly settles down about him as the train rushes on.

"I change my title twice within twenty minutes. The Pullman conductor, as he collects my berth fare, dubs me 'Captain.' He hails from St. Louis, where captains are plentiful on the Mississippi River boats. Shortly comes along the regular train conductor, a portly gentleman from Louisville. True to his Kentucky instinct, he calls me 'Colonel.' I am not possessed of that universal accompaniment of a Kentucky Colonel, a bottle of moonshine or old Bourbon whiskey but I have the next thing to it, a flask of Burgundy wine, so here's to the health of the train conductor who raised my rank on first sight. Long may he live and prosper! At the present rate of promotion I shall be a Major-General many hours before I reach my destination."

Aside from his numerous short contributions, Blatchley is the author or co-author of four magnificent entomological volumes which will ever stand as monuments to his achievements in his favored field of science. I refer, of course, to his books on the Coleoptera, Rhynchophora, Orthoptera and Heteroptera. A year ago he published his "Blatchleyana," which includes a list of his published writings and a chronology of his life. This gives to us in graphic form the wonderful achievements in a variety of fields by a single individual.

E. Bruce Williamson (fig. 4), is another entomologist who has brought fame to Indiana as an international authority. He has collected and studied dragon flies (Odonata) in every section of the State and has in addition collected in other states and in South America. He is a past president of this Academy.

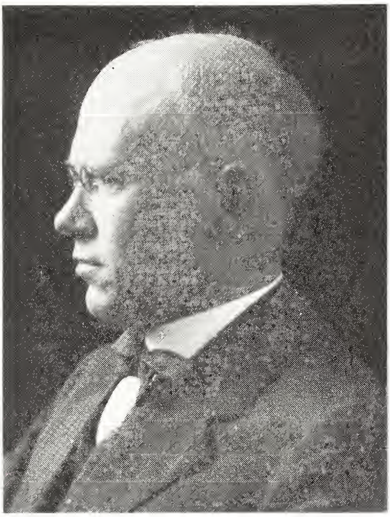

Fig. 4. E. B. Williamson.

In 1929 he gave his large collection of Odonata to the University of Michigan and since that date has been Research Associate of the Zoological Museum of that institution, although continuing to spend six months of each year at his justly famous iris breeding farm at Bluffton. Williamson has published about 115 papers (1900-1931) on the Odonata, and to him we owe our complete knowledge of the Odonata fauna of Indiana.

I have referred to the three men—Say, Blatchley and Williamson—who have made outstanding contributions to the entomology of Indiana. Several others, who will be referred to later, should be included among the important contributors to Indiana Entomology. Among these are Kinsey for his work with the gall wasps (Cynipidae), Montgomery with the dragonflies (Odonata), Morrison and Dietz with the scale insects (Coccidae), and Webster in economic entomology.

Many others contributed to our knowledge of the insects of the State, and we will here briefly refer to their interests and contributions.

George Mitten (fig. 5) was born in England in 1826 where as a boy he became interested in entomology and made an extensive collection, which, however, was left in his native home when he came to America in 1875. Upon his arrival in America, Mr. Mitten went to Goodland where he resided for 31 years or until 1906. It was during this period that he was most active as an insect collector, at first using cigar boxes for his collections, later substituting spool-thread cabinets and later transferring his extensive collections to mahogany cabinets.

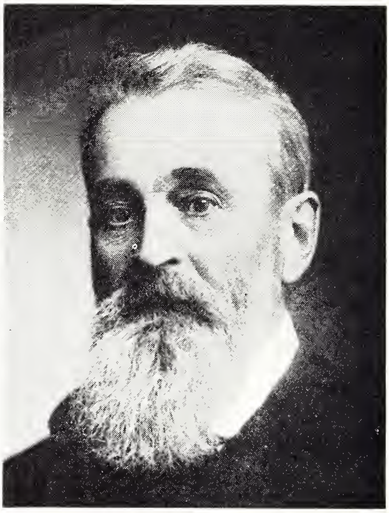

Fig. 5. George Mitten, 1826-1916.

Mr. Mitten was not only a collector. During the summer months he was almost continuously engaged in rearing specimens, collecting the eggs or larvae or pupae and observing their development. Although interested primarily in butterflies and moths, Mr. Mitten was interested in insect life in general.

Two cabinets of this excellent collection were presented to Purdue University a few years ago by Arthur Mitten, a son of George Mitten.

It is interesting to note that George Mitten's brother was a prominent English botanist whose daughter married the great scientist Alfred Russell Wallace.

The Mitten Memorial Building, recently erected at Goodland, Indiana, bears a tablet to George Mitten which reads as follows:

> "He was a Christian gentleman, a kind father,
> A lover of Nature and good books."

Samuel G. Evans (fig. 6) was born in Virginia in 1839 and being much interested in the natural sciences, he prepared himself to teach this subject, even though such studies were not in much favor at the time. Shortly after the Civil War he located at Evansville, his home until his death in 1929. He had an ardent interest in all of the sciences, study-

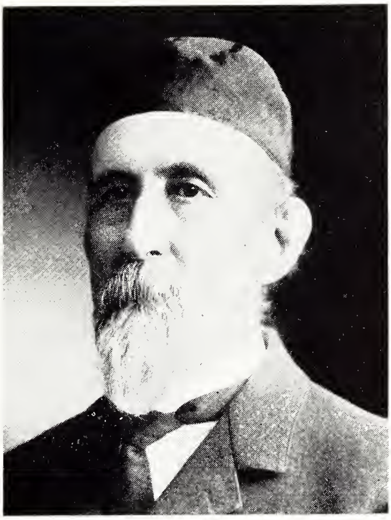

Fig. 6. Samuel G. Evans, 1839-1929.

ing at one time or another birds, Indian relics, fossils, shells, minerals, and wild flowers. He was actively interested in the collection of insects, particularly butterflies and moths for 35 or 40 years, and his collection

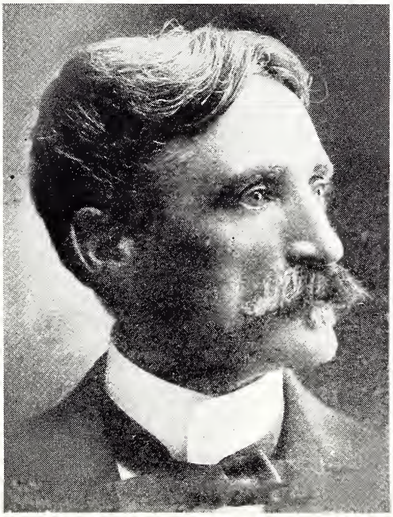

Fig. 7. R. J. Weith, 1847-1902.

of Lepidoptera was one of the finest ever made in the State. According to the Academy Proceedings he prepared a paper dealing with certain groups of Lepidoptera in 1890, but the paper was never printed. Some

30 years ago some energetic and enthusiastic Evansville people planned a museum and induced Mr. Evans to deposit his fine collection of butterflies and moths in the museum. However, the appointment of a curator did not materialize and as a result the valuable material accummulated over a period of 40 years, has long since gone the way of many another fine collection and lost to future generations by museum pests. Mr. Evans was a business man of Evansville but appreciated not only the pleasures of collecting specimens but of associations with others interested in the sciences and was a member of the Indiana Academy of Science and of the American Association for the Advancement of Science.

R. J. Weith, (fig. 7) a native of Posen, Germany, where he was born in 1847, came to the United States and located at Elkhart in 1865 at the age of 18. He died in Elkhart in 1902. He was an extensive collector and is best known for his work in Hymenoptera and Odonata, in which branches he made some interesting discoveries and captures although I believe did not himself publish his observations. He was a member of the Entomological Society of Washington. His collection is scattered, having been given to the schools of Elkhart and to friends.

Dr. T. G. M. Levette of Indianapolis was one of the best all around naturalists of the State and accumulated a large collection of beetles. Very little is known of this man except that he was an assistant in the State Geologist's office from its organization in 1869 until 1878 or possibly later. During this time he carried on various lines of work, including surveys of the northern Indiana lakes, although he was apparently engaged during most of his service in chemical and metallurgical analyses.

An extensive collection of beetles which was purchased by T. L. Casey in 1890, and which is now with the Casey Collection in the U. S. National Museum, was made by Levette, but according to those who have seen the material, few of the specimens carried locality or date labels although presumably most of the insects came from Indiana.

Dr. F. Stein, a German physician who practiced medicine in Indianapolis, accumulated an excellent collection of beetles (Coleoptera). Although he collected extensively in the State, unfortunately he paid little attention to properly labeling his specimens. Blatchley became acquainted with him about 1890 and frequently came to Indianapolis from Terre Haute on week ends to study the collection and exchange ideas. The collection was given to a friend who knew nothing of the care such a collection required and as a result museum pests destroyed most of the specimens, the remaining few hundred being turned over to Blatchley who retains them in his collection. It is interesting to note that during President Benjamin Harrison's administration, Dr. Stein was appointed Superintendent of Improvements on the Wabash River below New Harmony. While here he made extensive collections of shells and beetles. The collection of shells is now in the Field Museum at Chicago.

W. P. Shannon, (fig. 8) a fellow in the Indiana Academy of Science, was an early student of Indiana insects and at the December, 1887, meeting of this Academy he presented a paper entitled "A list of the butterflies of Decatur County, Indiana." This paper was never published. He was a very good general naturalist, interested in every branch of natural science and made collections and observations not only on insects but on fishes, birds, shells, plants, fossils, minerals and Indian relics. His collections are scattered and probably much of the material lost because of improper care. His collection of butterflies, moths and beetles, for example were purchased by Mrs. Shannon's brother, then superintendent of the Evansville schools, for that institution, but so far as we can learn they have long been lost to science by neglect and the depredation of museum pests. Mr. Shannon was principal or superintendent of the Greensburg, Indiana, schools from 1875 till his death in 1897.

Fig. 8. W. P. Shannon, 1847-1897.

George C. Hubbard was a member of this Academy and an insect collector who furnished Blatchley with records of butterflies collected in the vicinity of Madison. Hubbard was a resident of Moores Hill and presented papers before the Academy in 1887 and 1888 on the butterflies and the solitary wasps of Jefferson County, but so far as can be learned neither paper was published. He died about 1895.

Mel T. Cook, at present Vice-Director of the Insular Experiment Station of Porto Rico, was connected with the Biology Department of DePauw University from 1895 to 1904 and although a plant pathologist, he contributed several papers on the insect galls of Indiana, one in the 29th Annual Report of the Geological and Natural Resources of Indiana for 1904, and two in the Proceedings of the Indiana Academy of Science for 1907 and 1908, respectively.

J. Speed Rogers, born at Dayton, Indiana, in 1892, is one of the few outstanding specialists on the crane flies or Tipulidae. Rogers has collected extensively in Indiana, especially in Jefferson and adjacent counties during the summers of 1919, 1921, 1922 and in the fall of 1930 and spring of 1931. In a recent letter he writes: "Have found Jefferson County a very interesting and profitable place to work and between the deep ravines, such as Clifty Falls State Park and the flats and beech woods, have found a very rich fauna with surprising mixtures of northern, southern and western crane flies." He advises further that 200 species of Tipulidae were collected in southern Indiana and much life history and ecological data obtained which will soon be published.

O. S. Roberts, at present connected with the State Chemist's Office, made extensive collections, especially Lepidoptera, in the vicinity of his home at Lafayette. He also assisted Webster, during his connection with Purdue University, mounting and caring for specimens collected and reared by Webster.

Walter N. Hess, a member of this Academy and until recent years a member of the Zoology Department staff of DePauw University, taught a course in general entomology at that institution, which was offered every other year. Hess was interested in entomological research and in spite of his instructional duties was able to conduct investigations which resulted in the publication of two papers on the biology and morphology of fire flies (Lampyridae).

Will P. Morgan has made a number of excellent contributions, all of which have been published in the Proceedings of this Academy (1924-1927). His studies have dealt with the morphology and physiology of earwigs (Dermaptera).

C. F. Adams. Indiana is indeed fortunate in having acquired another outstanding entomologist. I refer to C. F. Adams, Director of the Bacteriological Laboratory of the Indiana State Board of Health. Previous to coming to Indiana, April 1, 1927, Doctor Adams was collaborator with the world-famous dipterist, W. S. Williston, and director, dean and entomologist of the Arkansas Agricultural College and the Arkansas Agricultural Experiment Station. It was during this time that he became recognized as one of the outstanding authorities of Diptera. His first collection, developed previous to severing his connections with Arkansas on account of his health, was left with the Arkansas Agricultural College. His collections since that date (1913), were recently donated to Purdue University. Doctor Adams is now carrying on special studies of the fungus gnats (Mycetophilidae) of the world and the mosquitoes (Culicidae) of Indiana.

The Dunes Region of Northwestern Indiana has proven an attractive and profitable collecting grounds and several insect collectors of Chicago have made frequent and extensive collections in that area. Wm. J. Gerhard of the Field Museum has provided me with information on these Chicago collectors as follows:

Emil Beer collected Lepidoptera from 1898-1930. Most of the specimens collected are in his personal collection.

Wm. J. Gerhard was an active collector of all orders from 1903 to 1925 and all of the material, with the exception of the Hemiptera, are in the Field Museum. The Hemiptera are in his personal collection.

Emil Liljeblad collected Lepidoptera and Coleoptera in Northern Indiana from 1883 to 1925 and his entire collections, with the exception of the Mordellidae (Coleoptera), are in the University of Michigan Museum of Zoology at Ann Arbor.

A. B. Wolcott collected Coleoptera during the period 1902-1925, and has made special studies of the beetle fauna of the tamarack swamp near Mineral Springs. With the exception of the family Cleridae, all of his beetles are in the possession of Dr. F. J. Psota of Chicago.

Alex K. Wyatt has been an active collector of Lepidoptera in Northern Indiana since 1898 and with few exceptions all of his material is retained in his private collection.

INSTITUTIONAL ACTIVITIES

Indiana University. Although Indiana University does not have a separate department of entomology, courses in entomology are given. According to W. S. Blatchley, the first course was given in 1886 by J. C. Branner, geologist of the institution and president of the Indiana Academy of Science in 1889. Blatchley recalls only three members of this class, Charles Boleman, Jerome McNeill and himself, all of whom became recognized authorities. Boleman graduated from the University and became the American authority on Myriopoda but died in 1889, soon after his graduation, of malarial fever in Wycross, Georgia, at the age of 21. McNeill graduated in 1886 and later became an authority on the Orthoptera, publishing a number of excellent papers although none especially referred to the fauna of Indiana. The marvelous achievements of Blatchley, the dean of Indiana entomologists, who is without doubt one of the outstanding entomologists in America, have already been discussed. Since Branner's time no courses in entomology have been given at Indiana University, as far as I can find, until A. C. Kinsey came to that institution in 1920. Previous to this time several graduates of Indiana University, specializing in Zoology, have become well known or very prominent American entomologists. These include T. J. Headlee, head of the Entomology Department of Rutgers College and the New Jersey Agricultural Experiment Station; C. H. Kennedy, Professor of Entomology of Ohio State University and an authority on the Odonata; Leonard Haseman, Head of the Entomology Department of the University of Missouri and the Missouri Agricultural Experiment Station; W. L. McAtee, of the U. S. Biological Survey, who has made notable contributions to our knowledge of the insect food habits of birds; N. E. McIndoo, of the U. S. Bureau of Entomology, who is a recognized authority on insect physiology; and George Shafer who has made notable studies on various phases of entomology, especially on how insecticides kill. Although, as far as I know, S. A. Forbes, Dean of Amercan Entomologists, never carried on studies in Indiana, Indiana University may well be proud of the Ph.D. degree which they bestowed on this unsurpassed entomologist, in 1884, whom I am proud to know as my teacher and later my chief. According to records this degree was conferred "by examination and thesis" as a result of private study, although Forbes had taken no academic course and did not hold a bachelor's degree.

Since Kinsey came to Indiana in 1920 more emphasis has been given the subject of entomology. Kinsey's studies of the Cynipidae or gall wasps have a nation-wide if not a world-wide influence and are recognized as among the most notable taxonomic and phylogenetic contributions in entomology. Under Kinsey two students have completed Ph.D. requirements, namely Ralph Voris and H. T. Spieth.

Purdue University. Entomology had its beginning at Purdue University in 1884. It was in that year that Francis Marion Webster (fig. 9), one of the outstanding economic entomologists this country has ever produced, came to Lafayette as Special Agent of the U. S. Department of Agriculture and Consulting Entomologist of the Purdue University Agricultural Experiment Station. Although not a college graduate, he showed a great interest in nature and in matters scientific. Being a farmer in northern Illinois during his early life, he recognized the many insect problems confronting the corn grower and made careful observations and practical deductions for control recommendations. As early as 1874 he published newspaper articles suggesting methods of insect control. The first real work in economic entomology in Indiana was done by Webster during his residence at Lafayette from 1884 to 1891. His writings appeared in the Proceedings of the Indiana Acad-

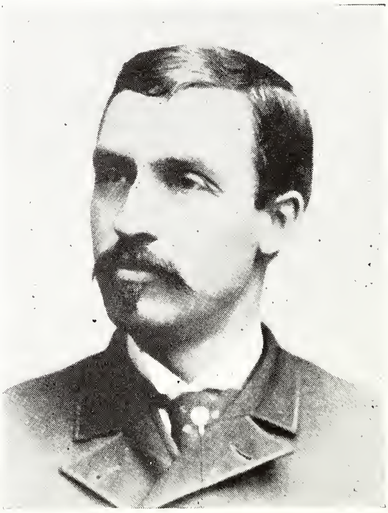

Fig. 9. F. M. Webster, 1849-1916. Photograph furnished by L. O. Howard; taken about 1891 when located in Indiana.

emy of Science as well as in other state and federal publications and it is of special interest to note that Webster wrote the first bulletin of the Purdue University Agricultural Experiment Station as Bulletin No. 1, The Hessian Fly, Dec. 30, 1884 (1885). Webster later became chief of the Division of Cereal and Forage Insects of the U. S. Department of Agriculture, which position he held until his death in 1916, at the age of 66.

Indiana owes much to Webster, not only for the work which he did while located in the state but also because he continued his interest in the entomology of the state, evidenced in part by the fact that he established one of his first federal field stations in Indiana in 1905.

The same year Webster came to Indiana, James Troop (fig. 10) arrived at Purdue as Head of the Department of Horticulture and Entomology. During his early connection with Purdue, Troop gave instruction in a variety of subjects, including horticulture, entomology, agricultural botany, forestry, and veterinary science. He continued as Head of the Department of Horticulture and Entomology until 1912 when the department was divided, Troop retaining the headship of the Entomology Department, which position he held until 1920. Since that time he has been essentially Professor Emeritus, which position he holds at this date. As second oldest man, in point of service, at Purdue University, Professor Troop has been actively associated with the institution for 47 years.

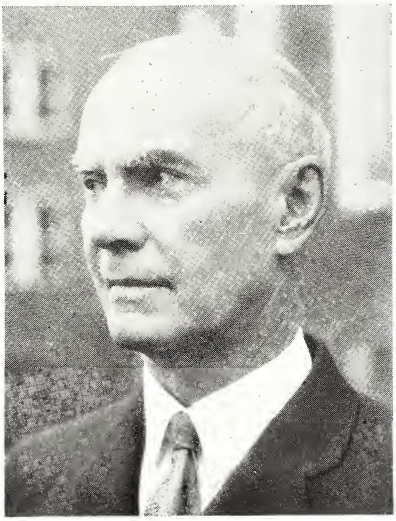

Fig. 10. J. Troop.

Until 1910 Troop was the sole instructor in Entomology at Purdue. In that year P. W. Mason came to Purdue as assistant instructor, remaining with the school until 1914.

In 1914, W. A. Price was appointed to take the position left vacant by the resignation of Mason. Price remained until June, 1929, at which time he was Associate Professor of Entomology.

J. J. Davis became head of the department in 1920, which position he now holds. Thus it is observed that for a period of 47 years (1884-1931), the headship of the department has been held by but two persons.

During the scholastic years 1923-24 and 1924-25, G. M. Stirrett was laboratory assistant and from 1925-1927 C. O. Dirks was instructor during the illness of Professor Price.

H. O. Deay came to Purdue in February, 1929, and B. E. Montgomery in September, 1929, both men still retaining membership on the Purdue instructional staff.

The present personnel of the Department of Entomology of Purdue University is J. J. Davis, Head; J. Troop, Professor Emeritus; H. O. Deay and B. E. Montgomery, Instructors.

Until 1928 the Department of Entomology was solely a service department, providing instruction in entomology for students specializing in the various lines of Agriculture. In 1928 a special curriculum was provided for students wishing to specialize in the subject and at the present time the Department provides the following courses: seven courses strictly for undergraduates including an introductory course and courses in fruit and garden insects, field crop insects, entomology for education students, forest entomology, greenhouse insects, pharmacal entomology and beekeeping; three courses available to undergraduate and graduate students, in insect physiology, morphology and taxonomy and entomological problems; four courses solely for graduate students, which include advanced economic, special research and seminar.

Since the introduction of the entomology curriculum in 1928, nineteen students, not including graduate students, have enrolled for entomology, and previous to 1930 the following who have taken up entomology as a vocation have received graduate or undergraduate degrees from Purdue University: G. M. List, P. W. Mason, W. H. Larrimer, G. M. Stirrett, B. E. Montgomery, S. W. Clark, K. A. Haines, H. K. Rippey and C. D. Herod.

The Purdue University Agricultural Experiment Station has maintained an entomology department for practically the same period as the same department directing the instruction work, and with the same heads, namely James Troop until 1920 and J. J. Davis since that date. The entomologists connected with this research division of the institution include the following: C. R. Cleveland (1922-1927), H. K. Riley (1927-1931), G. A. Ficht (1927-date), L. F. Steiner (1927-1930), G. E. Marshall (1930-date) and G. E. Gould (1931-date). Field laboratories are maintained at Bedford, for fruit insect investigations, at Warsaw for garden and canning crop insect investigations and at Monroe, Michigan[8], in co-operation with the U. S. Bureau of Entomology, for corn borer studies.

Ever since the organization of Extension work at Purdue the entomologists of the Station and teaching staff have been active in extension activities although funds have never been available for so-called extension specialists in entomology. The federal Department of Agriculture provided an extension bee specialist from 1918-1920, this position being held during that time by E. G. Baldwin.

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[8] Entomological corn borer studies are largely conducted outside of the State at present because of the comparatively small infestation in Indiana.

In addition to these field laboratories maintained by the Experiment Station, two federal entomological laboratories, with which active cooperation is maintained by the Purdue Station, are located in the State. One is the U. S. Cereal and Forage Crop Insect Laboratory at West Lafayette and the other the U. S. Deciduous Fruit Insect Laboratory at Vincennes.

U. S. Cereal and Forage Insect Laboratory. Recognizing the necessity of establishing field laboratories at strategic points throughout the United States the late Prof. F. M. Webster, in charge of cereal and forage insect investigations, established the first federal laboratory in Indiana at Richmond in 1905, with W. J. Phillips in charge. This laboratory was transferred to West Lafayette in 1909, with headquarters in the Purdue Experiment Station Building until 1913 when a separate building nearby was leased to accommodate the enlargement of the work. Phillips remained in charge until 1913 when he was succeeded by J. J. Davis who continued in charge until 1919. From 1919 and 1925, the laboratory was in charge of W. H. Larrimer. W. B. Cartwright was temporarily in charge in the interim (Aug., 1925-Aug., 1926) between Larrimer's leave and the permanent appointment of C. M. Packard, who is the present entomologist in charge of this important laboratory.

During the period 1905 to date the following entomologists have been connected with this laboratory: W. J. Phillips, 1905-1913 (in charge, 1905-1913); T. H. Parks, Apr. 1909-July, 1909; Philip Luginbill, March, 1910-July, 1912; J. J. Davis, March, 1911-Jan., 1919 (in charge, 1913-1919); C. W. Creel, Aug., 1911-Sept., 1912; Henry Fox, Sept., 1912-Nov., 1913; A. F. Satterthwait, April, 1913-Dec., 1916; R. J. Kewley, 1914-1916; D. G. Tower, 1915-1916; F. A. Fenton, Sept., 1915-Sept., 1916; W. H. Larrimer, Dec., 1916-Aug., 1925, excepting during Army service, 1917-1919 (in charge, 1919-1925); J. M. Aldrich, 1917-1918; W. O. Hollister, March, 1918-March, 1919; R. J. Fiske, March, 1919-March, 1920; A. L. Ford, March, 1919-May 1920; C. F. Turner, July, 1919-Sept., 1919; F. L. Simanton, Sept., 1919-March, 1920; R. A. Blanchard, April, 1920-Sept., 1920; W. B. Cartwright, May, 1920-Aug., 1926 (in charge, 1925-1926); S. Blum, May, 1920-Sept., 1920; H. R. Painter, Sept., 1920-date; G. B. Pearson, Sept., 1920-May, 1922; W. B. Noble, June, 1922-date; Curtis Benton, July, 1924-date; C. M. Packard, Aug., 1926-date (in charge, 1926-date), and Geo. G. Ainslie, Nov. 1929-Dec., 1930.

During this period of over 25 years, many important studies have been made. From 1909 to 1913, under the direction of W. J. Phillips, the important studies included the wheat jointworm and aphids. From 1911 to 1919, under the direction of J. J. Davis, emphasis was given to the white grub problem, although much progress was made on a study of several species of aphids, the extensive Hessian fly sowing plots were begun and cutworm studies were started. It was during this interim, at the time of the war when wheat and wheat products were scarce, that studies were made which permitted substitution of sawdust for bran in cutworm and grasshopper poison baits. From 1919-1925, under W. H. Larrimer, the Hessian fly was the major project although grasshoppers and other clover and grass insects were important projects. Under the direction of C. M. Packard, the Hessian fly continued as the major project, although other studies of importance were undertaken, including webworms, cutworms and clover insects.

Federal Deciduous Fruit Insect Laboratory. Because of the demand for federal assistance in studying the many insect problems of the fruit grower in the central west, Dr. A. L. Quaintance, in charge of deciduous fruit insect investigations of the U. S. Department of Agriculture, established a laboratory at Vincennes, with B. A. Porter in charge, in 1923. This was truly a co-operative laboratory as the Purdue Station and the growers in the vicinity contributed funds to aid the work. The San Jose scale and peach tree borer investigations which had been conducted by the Purdue entomologists since 1921 were turned over to the federal agents and they also inaugurated research on several other important problems, including the tarnished plant bug and codling moth. In October, 1929, after Porter's transfer to the Washington office, F. H. Lathrop was placed in charge. Lathrop continued the investigations inaugurated by Porter and started new studies as conditions demanded, especially detailed studies of insecticides for orchard use.

In 1929 a rather limited series of experiments with baits for attracting the Oriental fruit moth yielded such promising results that the project was greatly enlarged and W. P. Yetter, Jr., was placed in charge of extensive experimental orchard work of trapping the Oriental fruit worm moths, inaugurated in 1930.

The personnel of the laboratory since its establishment is as follows: B. A. Porter, 1923-1928 (in charge, 1923-1928); R. A. Sazama, Nov., 1925-date; W. P. Yetter, Jr., May, 1929-date; F. H. Lathrop, Oct., 1929-date (in charge, 1929-date), and James Cooper, April, 1930-date.

Much of value to the Indiana fruit grower has been accomplished by the work of this laboratory, including investigations leading toward the solution or improvement of controls of the major fruit insect problems of southern Indiana.

Federal Vegetable Insect Laboratory. For a few years the U. S. Department of Agriculture maintained a laboratory at Plymouth for the investigation of truck crop insects. H. K. Larrimore, a graduate of Purdue, was first in charge of this station. M. R. Smith was connected with this laboratory from June, 1917 to September, 1918, being in charge during 1918. During that last year of the existence of the station, Smith was assisted by J. M. Craig. Incidental to the economic studies, Smith made a study of the syrphid fly fauna of that area and published a list of 45 species of the family Syrphidae (Diptera) collected during the summer of 1918 in the vicinity of Plymouth.[9]

State Entomologist's Office. The original Indiana San Jose Scale and Nursery Inspection Law was passed by the State Legislature in 1899 and the enforcement was in charge of James Troop, Indiana's first

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[9] Can. Ent., vol. 51, Dec. 1919, p. 273.

State Entomologist, until the reorganization and establishment of the present State Entomologist's Office at Indianapolis in 1907.

The original law was passed to control the San Jose scale and avoid spread of this insect in particular, on nursery stock. The present office of State Entomologist was later created to take care of the increasing regulatory obligations. At present this office enforces quarantine regulations as they refer to insects and diseases, as well as nursery and apiary inspection. Although originally an independent office the State Entomologist's Office became a part of the Department of Conservation with the origin of that department in 1919.

Since the organization of the present State Entomologist's Office, three persons have occupied the office. The first appointee under the new organization (the second State Entomologist of Indiana) was B. W. Douglass, June 10, 1907, who was replaced by C. H. Baldwin Jan. 1, 1911, the latter continuing until Jan. 1, 1915. The present State Entomologist, F. N. Wallace was appointed Jan. 1, 1915.

Since the organization of this office the following men with some entomological training have been connected with the State Entomologist's office: B. W. Douglass, 1907-1913 (State Entomologist, 1907-1912); F. N. Wallace, 1908-1912, 1915-date (State Entomologist, 1915-date); Max Ellis, 1908-1912; Harry F. Dietz, 1909-1916 (excepting few intervals), 1920-1929; C. H. Baldwin, 1909-1915 (State Entomologist, 1911-1915); Harold Morrison, 1910-1914, 1915-1916; A. P. Swallow, 1912-1915; M. E. Kimsey, 1913-1917; Paul Ulman, 1915-1917, 1926-date; R. E. Snodgrass, 1915-1917; R. W. Kelty, 1917-1918; Phillip Spong, 1917-1919; Everett White, 1924-1930; E. Walters, 1926-1927; M. F. Miller, 1927-1931; D. H. Schultz, 1926-date; F. E. Sheaffer, 1927-date; R. K. Rippey, 1930-date, and O. V. Lopp, 1931-date.

There is not time to comment on the activities of each of these men, but particular reference must be made to three of these men, Dietz, Morrison and Snodgrass, who are outstanding entomologists in this nation, although, unfortunately no longer working in the State.

Harry Dietz is well known to every member of this Academy for his active services in its promotion. Dietz has a knowledge of entomology in its broadest sense. He is an authority on greenhouse insects and coauthor with Morrison in the preparation of a notable taxonomic paper, "The Coccidae of Indiana."

Harold Morrison, at present curator of the Division of Insects of the U. S. National Museum, was an active student of Indiana insects and is now recognized as an international authority of the Coccidae.

R. E. Snodgrass wandered westward to Indiana with an artist friend early in 1915. Being interested in entomology he visited the entomologist's office in the State Capitol at the time Dietz and Morrison were at work on the Coccidae of Indiana. He was engaged to prepare illustrations for this study and remained with the office until the fall of 1917, preparing illustrations and conducting insect studies. At the present time, as a member of the staff of the U. S. Bureau of Entomology, Snodgrass has become one of the outstanding authorities on insect physiology and morphology.

The State Entomologist's Office, since 1908, has conducted inspections of apiaries, with special reference to foul brood disease. The chief inspectors since the organization of this work were as follows: Geo. S. Demuth, 1908-1911; B. F. Kindig, 1912-1916; C. O. Yost, 1918-1931; J. E. Starkey, 1931-date.

All have been outstanding in their particular field. Special mention should be made of George Demuth who was born near Peru where he established an apiary in 1885 at the age of 14. In 1911 he carried on extensive and important research in beekeeping for the U. S. Department of Agriculture, continuing his official connections with that department until 1920, since which time he has held responsible connections with the A. I. Root Company. He still maintains several commercial apiaries near Peru.

Nine reports were published previous to 1919 when the office became a division of the State Department of Conservation. Since that time brief reports have been issued as a part of the Department of Conservation report.

ORGANIZATION ACTIVITIES

Entomological Organizations. Shortly after assuming his duties with Purdue University in 1920, the speaker, appreciating the value of close contact and association with colleagues in adjoining states where conditions are similar and warrant practically identical control recommendations, called a meeting of entomologists of the North Central States. At this first conference in 1921, four states and the federal government were represented by H. A. Gossard and T. H. Parks of Ohio, S. A. Forbes and W. P. Flint of Illinois, L. Haseman of Missouri, J. J. Davis of Indiana and W. H. Larrimer of the Federal Bureau of Entomology (fig. 11). This conference proved so successful that a similar conference has been held every year since 1921, excepting in

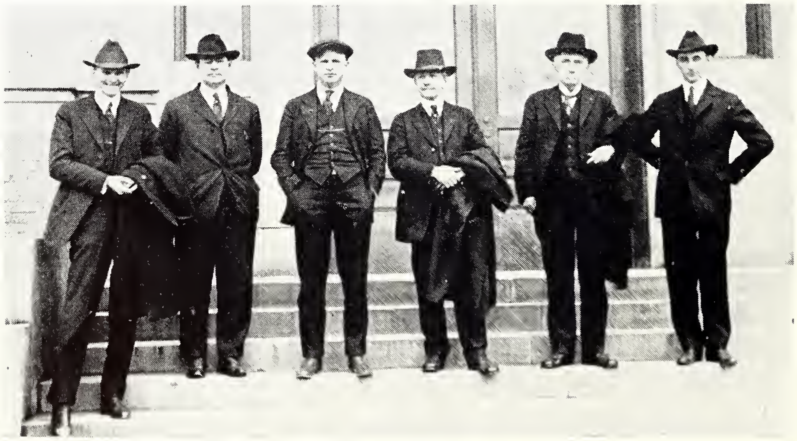

Fig. 11. The first North Central States Entomologists' Conference, held at Lafayette in 1921, was attended by the men in this group who from left to right are: T. H. Parks of Ohio, L. Haseman of Missouri, W. H. Larrimer of the U. S. Bureau of Entomology, H. A. Gossard of Ohio, S. A. Forbes and W. P. Flint of Illinois.

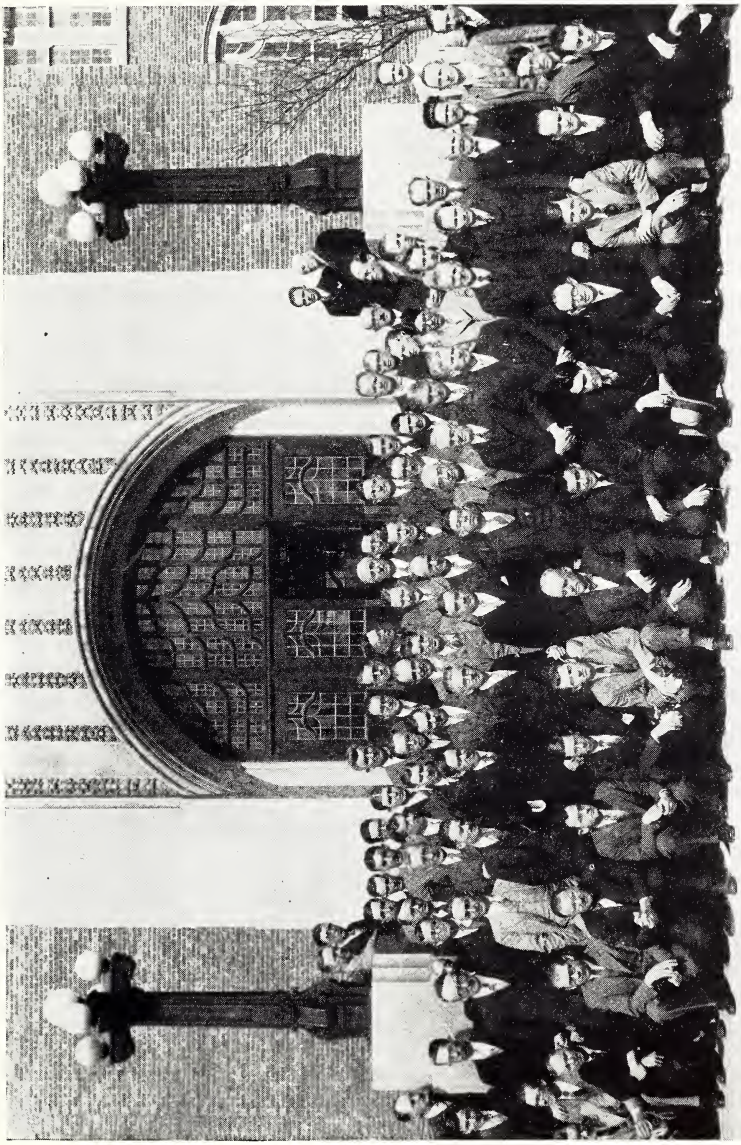

Fig. 12. Annual meeting of the North Central States Entomologists held at Lafayette, March, 1930. Note growth of this organization by referring to figure 11, showing the group nine years before.

1922. The 1925 and 1930 conferences were also held at Lafayette at which meetings 30 and 78 entomologists (fig. 12) attended each meeting, respectively. This will give you some idea of the recognized appreciation of such conferences.

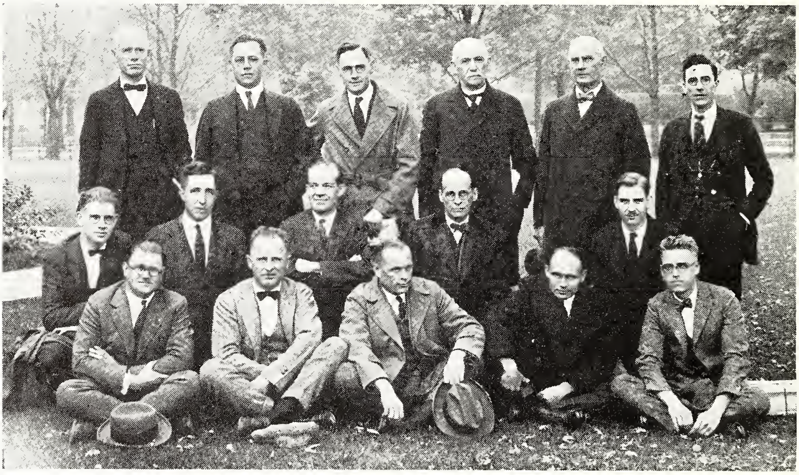

Fig. 13. First conference of Indiana entomologists held at Lafayette, October 26, 1923. Lower row from left to right: B. E. Montgomery, W. H. Larrimer, W. A. Price, H. F. Dietz, A. C. Kinsey. Second row: W. B. Noble, C. R. Cleveland, L. Greene, F. N. Wallace, G. M. Stirritt. Back row: E. B. Williamson, H. R. Painter, B. A. Porter, W. S. Blatchley, J. Troop, J. J. Davis.

Fig. 14. The first outing of the student Entomological Society of Purdue University, May, 1928.

Two years later a meeting of all persons interested in entomology in the State was called, the object being to develop a better understanding and co-operation within the State. This conference was held at Lafayette October 26, 1923, and was attended by 15 persons as follows: W. S. Blatchley, C. R. Cleveland, J. J. Davis, H. F. Dietz, A. C. Kinsey, W. H. Larrimer, B. E. Montgomery, W. B. Noble, H. R. Painter, B. A. Porter, W. A. Price, G. M. Stirritt, J. Troop, F. N. Wallace and E. B. Williamson (fig. 13). Here again the conference was so successful that it was decided to meet annually and to avoid repetition of meetings, it was decided to hold the meeting each year at the time of the State Academy Meetings.

More recently, students interested in insect study at Purdue University have organized an active society known as the Thomas Say Entomological Society of Purdue University. This Society meets each month during the school year and has biennial field trips or picnics, one in the fall and one in the spring (fig. 14).

JUVENILE INSECT CONTESTS

Realizing that the general public knows too little about the animals belonging to the important Class Insecta and further recognizing the need of a better understanding of insects and insect life by the younger generation who will soon be our active citizens, an insect collection contest was inaugurated in 1925 (fig. 15) for the Boys' and Girls' 4-H Club

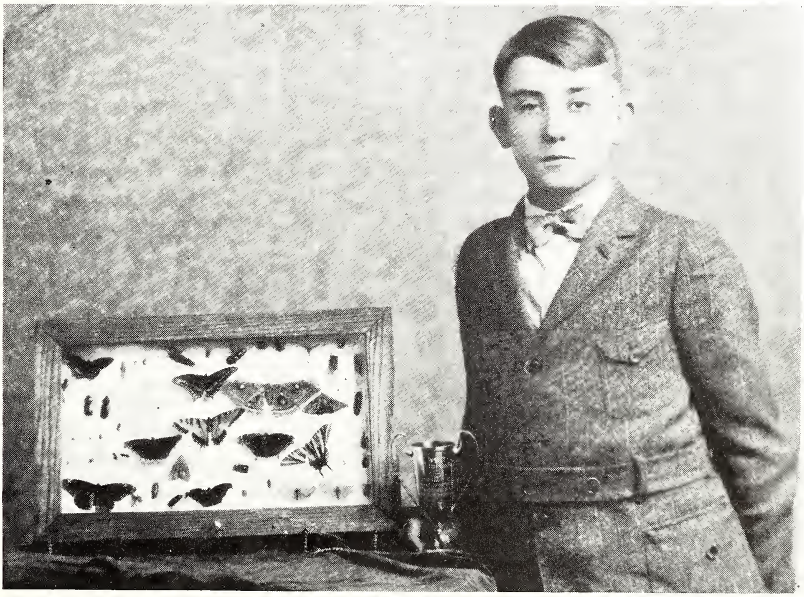

Fig. 15. The first Insect Collection Contest at the 4-H Club Round Up at Purdue in May, 1925, was won by Eldo Brown of Hartford City, Ind.

Round-Up, held annually at Purdue University. This contest has been continued each year since that date. An additional feature was started in 1929. This is known as the Insect Identification Contest and club members from all parts of the State have participated, 25 to 35 boys and girls entering the contest each year. In addition the State Board of Agriculture included a juvenile insect collection contest among the State Fair premiums, the first one being in 1928. As a result of these state-wide contests, several counties have arranged county contests, which have aroused much interest and competition.

There is no question regarding the value of such contests in arousing an interest and appreciation of natural history and in developing a keen sense of observation. In the opinion of the speaker, the Junior Academies of Science or Junior Science Clubs can be developed to best advantage if we can include not only insect collection contests but contests relating to all other branches of science sponsored by the State Academy.

BEEKEEPING IN INDIANA

Beekeeping has been practiced in Indiana, probably as long as Agriculture, and during the early history of the State most farmers kept a few hives of bees. Even at the present time a surprisingly large number of farmers maintain colonies of bees, although, unfortunately, very few properly care for them and not infrequently they become infected with foulbrood and are not only not profitable but are a definite menace to those who practice modern methods of beekkeeping.

It is interesting to note that the Indiana State Beekeepers Association was organized January 13, 1880, apparently following a preliminary meeting the year before. A report of this organization meeting, together with the constitution and by-laws, and proceedings of the meeting, was published in the report of the Indiana State Board of Agriculture for 1879.[10] A list of 62 members was given. For at least 10 years this organization apparently flourished, judging from the reports published in the State Department of Agriculture reports. The State Association exists today but whether the State Beekeepers Association has been a continuous organization since it started over 50 years ago I am unable to say.

RESULTS AND FUTURE OF ENTOMOLOGICAL RESEARCH IN INDIANA

Taxonomic Contributions. Early entomological studies necessarily required the description of the different kinds of insects found. Thus it was the problem of describing new species that confronted Thomas Say when he took up his residence and studies in Indiana. As already stated Say described hundreds of new species, over 400 from specimens collected in Indiana. After Say's death in 1834 practically no insect studies were made for over 50 years. With the coming of such men as Blatchley and Williamson, who, without doubt, have made the greatest contributions to our knowledge of the insect fauna of Indiana, entomological research has made steady and notable progress. The taxonomic works of these two men are outstanding and are recognized as authoritative studies, not only in Indiana but throughout the world.

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[10] 29th Ann. Rept. Indiana St. Bd. Agriculture for 1879 (1880), pp. 461-475.

W. S. Blatchley, who is still an active worker, and whom we are proud to have with us tonight, is responsible for the greatest amount of taxonomic work in the State. His work, however, includes not only Indiana but applies to the eastern half of the United States and the popularization of insect classification is largely through his published studies. I need call to your attention only his major published studies, including the following:

A Catalogue of the Butterflies known to Occur in Indiana, 1893.
Indiana Caves and Their Fauna, 1897.
The Orthoptera of Indiana, 1903.
An Illustrated Descriptive Catalogue of the Coleoptera or Beetles Known to Occur in Indiana, 1910.
Rhynchophora or Weevils of Northeastern America (with C. W. Leng), 1922.
Heteroptera or True Bugs of Eastern North America with Special Reference to the Fauna of Indiana and Florida, 1926.

E. B. Williamson, an international authority on the Odonata or dragonflies, is responsible for our complete knowledge of this order of insects in Indiana. His collection, which perhaps is unsurpassed, and which is especially rich in Indiana specimens, has been given to the University of Michigan Museum.

The Coccidae of Indiana (1916) by Harold Morrison and H. F. Dietz is a recognized authority, as are also the studies on the gall wasps (Cynipidae) by A. C. Kinsey. Other minor taxonomic studies have been published and at present Indiana has a group of taxonomic workers which assures a continuous output of valuable results.

A list of the families and orders of insects being investigated at the present time follows:

Orthoptera:[11] W. S. Blatchley and H. R. Painter.
Ephemerida: H. T. Spieth.
Odonata: E. B. Williamson and B. E. Montgomery.
Homoptera: H. O. Deay.
    Family Coccidae: J. M. Amos.
    Family Aphididae: J. J. Davis.
    Family Jassidae.[12]
Hemiptera: W. S. Blatchley and H. O. Deay.
Coleoptera:[13] W. S. Blatchley.

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[11] P. W. Mason made an excellent collection of Orthoptera and prepared a Masters' thesis on the Orthoptera of Indiana. The paper was never published and the collection is a part of the Purdue University Collection.

Henry Fox made intensive ecological studies of the Orthoptera in the vicinity of Lafayette. This paper was published in the Proceedings of the Indiana Academy of Science, 1914 (1915) pp. 287-321.

[12] No one within the state at present time. W. H. Larrimer made extensive collections when located in Indiana but he has not yet published.

[13] G. M. Stirritt made collections and studies of the fleabeetles (Halticini) for his Masters' degree thesis. The collection is with the Purdue University collections but his paper has never been published.

Families Carabidae and Cicindellidae: B. E. Montgomery.
Family Scarabaeidae: J. J. Davis.
Lepidoptera:
Rhopalocera: Robt. W. Montgomery.
Microlepidoptera: G. E. Marshall.
Diptera: C. F. Adams[14] and T. B. Harrison.
Hymenoptera:
Family Cynipidae: A. C. Kinsey.

Economic Contributions. A large amount of work on the control of harmful insects and the utilization of beneficial forms, commonly referred to as economic or applied entomology, has been done within the State and most of it within the past decade. Since the federal laboratories of the Bureau of Entomology of the U. S. Department of Agriculture and the Department of Entomology of the Purdue University Agricultural Experiment Station are organizations established primarily for research in economic entomology, most of the economic results have come from these institutions.

The results of these research laboratories have been published in government and experiment station publications and in the several entomological and research journals. The list is entirely too long to give at this time and I will merely briefly list the problems on which important and valuable results have been obtained. They include the following subjects:

Field Crop Insects: Wheat joint worm, Hessian fly, white grub, corn bill bugs, corn root aphid, cutworms, clover insects, European corn borer, and webworms.

Vegetable Crop Insects: Insects in relation to transmission of plant diseases, cutworms, potato leafhopper, greenhouse centipede, cabbage worm, striped cucumber beetle, blister beetles, mint flea beetle, false cabbage aphid, onion maggot, Mexican bean beetle, and squash vine borer.

Fruit Insects: Codling moth, Oriental fruit worm, peach tree borer, San Jose scale, and tarnished plant bug.

Shade Tree Insects: Cottony maple scale, elm scurfy scale, European elm scale, and oyster shell scale.

Animal Parasites: Poultry feather mite and cattle flies.

Stored Grain Insects: Wheat-infesting beetles.

Miscellaneous: Utilization of natural enemies for the control of introduced insects and studies tending to develop methods of predicting insect troubles.

I have taken more time than originally intended and yet I have given you but a hasty sketch of the entomologists of Indiana and their accomplishments in the scientific and economic fields of research. Insect study is no longer a hobby. Insects constitute a problem which can only be met by thorough and up-to-date research. We can well be proud of our predecessors and strive to carry on the work which has been so well begun.

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[14] At the present time Adams is making special studies of the mosquitoes (Culicidae) and fungus gnats (Mycetophilidae). J. Speed Rogers has made extensive collections and studies of the crane flies (Tipulidae) in southern Indiana and plans to publish his results in the near future.

THE INSPIRATION WHICH THE JUNIOR ACADEMY OF SCIENCE HAS BROUGHT TO THE HIGH SCHOOL SCIENCE CLUBS IN THE STATE OF ILLINOIS[1]

LOUIS A. ASTELL, Advisor, Illinois Junior Academy of Science.

Four phases of this subject are to be considered here: first, certain inspirational aspects of the history of the movement in Illinois; second, the principles which have been evolved and which may be counted upon to further enthusiasm among the sponsors and club members; third, certain personal results not already implied; and finally, the future of that academy and its relations to other academies.

I. Inspirational History. From the viewpoint of history the work in Illinois began in 1919. Mr. J. L. Pricer was Secretary of the Senior Academy at the time. His annual report[2] at the Jacksonville meeting included the recommendation that there be "a permanent committee of three on science education in the secondary schools." A nucleus of four high school science clubs was affiliated during that year. Of these clubs, the Danville Science Club, according to the records, is still affiliated. Over the country as a whole, science clubs may be found that have been in existence for 30 or more years, but as science clubs go, with changes in sponsorship as perhaps the greatest hazard of all, this record of a twelve-year affiliation is worthy of emulation. Science clubs can be kept alive from year to year through the inspirational incentives of a Junior Academy of Science.

In the ten-year period which began in 1919, the State Committee met with obstacles. At least twice in that decade, special efforts were made to keep the organization alive. First, there was a printed pamphlet and then a form letter. This information was sent to all recognized and accredited high schools in the State. Neither of these measures, qualitatively or quantitatively, were exactly what was needed. The affiliations gained in one season were lost in the next, if not in the same season. The story of three of the four science clubs, affiliated in one five-year period of that decade, has stood as an inspiration to me. An account of one of those clubs is briefly related in order that you may see some of the benefits a sponsor may obtain from this work.

In the third school of one sponsor's experience, and for the third time, a science club was organized and affiliated. Science clubs seemed indispensable to him. Affiliation with the State Academy of Science

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[1] This paper has been condensed from a paper read before the Indiana Junior Academy of Science in its first annual program at Butler University, Indianapolis, Indiana, December 5, 1931.

[2] Pricer, J. L., Secretary's Report in the "Transactions of the Illinois State Academy of Science," Volume XII., page 17, 1919.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

seemed indispensable to the welfare of his clubs. This time the club was some larger than either of the predecessors. There were perfections in detail at all points. A definite program of objectives was developed which reached out into the interests of the community. The club came to have a significant meaning to the members, to the school, and to the community through these activities and through the participation of its members in the annual meetings of the Junior Academy.

This time, contrary to the preceding cases, when his successor was to be chosen one of the requirements imposed by the Superintendent of Schools was that the new teacher be qualified and ready to continue the work of the club. That club is now in the second year of its healthy, desirable activity following the change in sponsors. The two other clubs became inactive in much less time, due to a lack of interest on the part of the science teachers, and due to a failure on the sponsor's part in demonstrating the importance of the work to the administrators.

At the Bloomington meeting, Miss S. Aleta McEvoy of Rockford, Illinois, was made chairman of the Section. Upon her suggestion, the "Illinois Junior Academy of Science," as we now know the affiliated group of high school science clubs, was christened. Emphasis was shifted from the problems of the teacher to those of the student club members. In the first year of her chairmanship, three new clubs were added to the roster. The following year there were twenty-two new clubs, and last year there were 24 more. The number of student delegates attending the annual meeting has kept pace with this growth. These statements may be taken as a general index to the inspiration which the Junior Academy affords the high school science clubs in Illinois.

For the committee in charge of the Junior Academy, it may be said that there are two chairmen, ordinarily; one for the High School Sciences, and one for the Junior Academy embracing the high school clubs. These chairmen have a joint relationship to the remainder of the committee. Thus, a compact committee of five including one college representative has served our needs very well up to the present time. It is a personal opinion, however, that if the annual competition expands much farther, there will be a need for an additional college representative or for another sponsor of an affiliated club. This additional member should be from the city in which the annual meeting is held.

The Illinois Junior Academy of Science is no longer an organism of perplexing constitution and health. Its present status is merely another reward for patience and perseverance; and another tribute to science as a body of knowledge which, in some respects at least, can be as inspiring as that for any other form of human endeavor.

II. Inspirational Principles. The outstanding principle, whether in the local or in the state activities of the affiliated clubs, is that the student members shall actually participate in the various phases of the work; that the organization shall exist primarily for the benefit of these members; that as in classroom work, the sponsors shall derive their personal inspirations through the benefits obtained by their students. This thought ultimately leads to the idea so aptly expressed by Whitman, when he said in effect that "he most honors my style, who learns under it how to destroy his teacher."

So it is that the Illinois Junior Academy of Science has a group of honorary state officers made up of club-member delegates from over the State. At the time of the annual meeting, these honorary officers perform the official induction ceremony[1] for the new clubs. These new clubs are represented by their own delegates in the ceremony. The major fields of science are considered in these annual programs. If an enthusiastic chemist gives the feature lecture, as did Doctor B. S. Hopkins at the Macomb meeting,[2] then another field of science is represented by the feature lecture the following year. We have found that one such feature lecture is sufficient for this audience. In addition to the ceremony and the lecture, there is usually an excellent scientific film, and a roll call of the various clubs responded to by a brief statement of the outstanding activity in which each specific club is engaged. The remainder of the morning is spent in examining the entries prepared and entered by the clubs as organizations and by the club members as individuals. This annual competition embraces posters, exhibits, and other projects.

Beginning this year, the awards for this annual competition are to be of the diploma type and will bear the signatures of the Academy officials. The engraved form will be the same for all events and places. This plan will make possible a greater variety of events, will give students an initial, inspiring contact of a permanent nature with the State leaders in science, and will mean a substantial saving in expense. Through the savings thus brought about, the printed magazine can be continued. It is hoped and planned that the annual issues of the magazine may be increased in number as the Junior Academy grows in order that all affiliated clubs may have an adequate voice in it.

No organization is more secure than its financial bases. For this reason, it seems that there should be some explanation of how, financially, both ends are made to meet. Our credited income depends on the following sources:

(1) Entrance and annual dues of clubs, sponsors, and others, obtained through the efforts of the Junior Academy officials and club sponsors.
(2) Commission on state-wide adoption of pins worn by students in all affiliated clubs.
(3) Advertising in the printed magazine.
(4) Annual contest entry fees.

It is true that the senior organization has made cash contributions and loans in the past, but it is not the policy of the Junior organization to be a financial parasite. Worth-while organizations should not have to be dependent. Financial independence of student organizations can be an important consideration in the training of these same students. In the first year of the present program of the Junior Academy, the receipts balanced the expenditures within five dollars. Every letter in the follow-up campaign was filled to the limit of postal regulations. These letters were signed but the salutations were to administrators and to science teachers in general, rather than to these individuals personally. Letters of this sort, unsealed, went for a cent and a half rather than for three cents. They were effective, because the envelopes were addressed to the individuals by name, because the series was timed and reached a climax in point of interest approximately two weeks before the annual meeting, and finally because personal requests for information resulting from the form-series were answered personally. Donations in the form of stenographic service and materials were in order then as they are today. Through such careful planning many things can be accomplished for a relatively small amount of money.

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[1] Astell, L. A., "Initiation ceremony of the Edisonian Science Club," School Science and Mathematics, 28:771-74 (Oct., 1928).

[2] Hopkins, B. S., "Opportunities in Science," Transactions of the Illinois State Academy of Science, 22:623-29 (May 3 and 4, 1929).

During the past year, some financial mistakes were made, but it is thought that the remainder of these mistakes was corrected at the last business meeting. One of these mistakes concerned the magazine, which was published without advertising. The supposition was that the local club sales of copies would cover the cost. This theory might be true for a greater number of affiliated clubs, or for a more adequate meeting of other factors, but it did not prove true for the number of clubs we had at the time. In all fairness, it should be said that the magazine was assembled in less than two weeks in order to be available at holiday time.

The method of handling the moneys is another matter worthy of attention. All receipts from the four sources referred to above pass through the hands of the Senior organization's Secretary and Treasurer. Likewise, the disbursements are made by the Senior Academy on authorized expenditure accounts, except for items of less than five dollars. This relieves the Junior Academy of auditing, and assures all concerned that there is no possible chance for misappropriation or other difficulty.

III. Personal Results Not Implied. Up to this point certain aspects of the history and of the principles, together with the general results incidental to these two phases of the problem, have been considered. There are other results reaching down into the lives and activities of the boys and girls, who wear the Junior Academy pins in Illinois. I shall mention a specific case.

The sponsor of one of the affiliated clubs found a boy member making a day-by-day clipping record of Byrd's South Pole Expedition and as a result built a "Pole to Pole" program around a half-hour talk by this gifted student. The program was presented while Byrd and his men were battling the ice pack. The boy's talk was on "Commander Byrd, His Life and Achievements." Parents of all club members were invited. The boy's talk brought out many things, but most important of all points was an open allegiance to his ideal among the daring and generous leaders of men. Naturally, the boy was one of the delegates to the annual meeting where he had an opportunity to hear Doctor Griffith Taylor's illustrated lecture, "With Scott in Antartica." The boy's enthusiasm could not be stated mildly. Here before him was the tramping ground of his own Commander Byrd; here another comrade of the icy wastes. While the boy was attending the University of Wisconsin as a freshman last year, Byrd came to Madison on his lecture tour. The boy must have been keeping an hour-by-hour record of his hero then. At any rate his desire to talk to Byrd personally, to know Byrd as Byrd's own colleagues had known him, became an overpowering influence. Byrd was a guest of the Governor at the moment. Without an invitation, the boy gained admission at the Governor's mansion to stand speechless from emotion in the presence of Byrd and others in attendance. Both Byrd and the Governor sensed the situation and put the boy at ease. That evening the boy sat with the Governor's party in the lecture hall. That evening a far away dream of one more aggressive American boy was fulfilled.

Different emphasis might be placed on the incident, but is it not true that what this boy did in the face of social custom for the sublimation of his interests, represents essentially what a scientist does in the face of accepted thinking to give a fundamental discovery to the world? Boys and girls, as you sit here today, I trust that your Junior Academy at some time and in some way may help to drive you as this boy was driven, beyond the matters of every-day existence to the infinitely important and numerous quests that shall have a profound meaning for your fellowmen. To be a personal leader and be so driven will be a lasting reward to your sponsors and a challenge to your associates.

IV. Inspirational Future. Concerning the inspirational future, it may be said that the Indiana Academy of Science, in making provisions for a Junior Academy, has done what several other State Academies have done or are preparing to do. These states lie in a more or less arc-like area through the United States. Beginning at the eastward, these academies are: North Carolina, West Virginia, Ohio, Indiana, Kentucky, Tennessee, Illinois, Iowa, Kansas, Oklahoma, and Texas.

The decade of experimental effort in Illinois has resulted in a three-year demonstration of enthusiastic response from the affiliated clubs. It has given us a few principles born of experience, and it has given a total of results beyond the expectations of those of us, who have worked longest and hardest over the idea.

For the two years just past, the Conference of the State Academies of Science has officially considered the development of the Junior Academy movement. My invitation to speak before the Conference at Des Moines, Iowa, in 1929 was issued by your Doctor Enders, then Chairman of the Program Committee.[1] Under Doctor Otis W. Caldwell, Chairman of the Committee on the Place of Science in Education, American Association for the Advancement of Science, last year, I was directed to render every possible service to the Junior Acadmy in Illinois and in other states as a part of my regular duties. Under the able guidance of such distinguished educators, we may be assured that in so far as this work merits support, such support will be found, just as support for the Junior Academy as a State organization in Illinois has been found, and just as now support for your organization here in Indiana is being found.

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[1] Astell, L. A., "How State Academies of Science May Encourage Scientific Endeavor Among High School Students," Science, 71:445-49 (May 2, 1930).

From the inherent nature of the Academy organizations, however, we may expect for the immediate future that the great contributions of the Junior Academies will be within rather than beyond their respective state jurisdictions. In all these activities, it shall be my personal pleasure to help the movement as much as I am able. I am sure the same may be said for all the officials in the Illinois Academy. To us, this is a matter of expressing our continued appreciation for the inspirations that have come to us in this work.

A MEASUREMENT OF GROWTH

F. M. ANDREWS, Indiana University

Of the many methods used in measuring growth some are very simple—but some of these are apt to lack the necessary accuracy required in certain studies. It is easy to see that certain plants or parts of them elongate when observed at considerable intervals of time even with the naked eye. Great differences have been observed in this respect, for the staminal filaments of Triticum may lengthen "from 4-7 mm. in two minutes." This is seen to be especially rapid for growth when compared with many lichens which may grow "not more than 2 to 5 mm. in the course of a year even under favorable conditions." Even here special means of observation are advisable. The growth of individual cells may be directly observed with a properly equipped microscope, or the growth of filaments from spores. In this case the conditions of growth that are most favorable can be easily controlled. Disturbances that are often present with the mechanism used in growth registration of higher plants can be avoided in these experiments. In such experiments the rapid growth of certain pollen tubes can be easily observed. For example, the pollen tube of *Torenia Asiatica* grows so rapidly, under these conditions, that the tube can be seen to move across the field of the microscope with comparatively low magnification. A cell generally attains its full size in length, breadth, and width before its walls begin to thicken. The reasons for this are obvious. But instances are known in which the same cell increases in size and thickens its walls at the same time. This frequently results in a retardation of communication between the cells concerned, although such functions may then be on the wane and a different function commence with new cells often appearing to assume the office of the original thin walled cells.

The horizontal microscope has long been used for the study of growth and other phenomena. The usual method of procedure is a study of elongation. The plant used here was *Rhizopus nigricans* grown on bread. Using an instrument with a scale whose spacing equalled .05 mm. between the lines it was observed that not only rapid elongation occurred, as is well known to this plant, but also that the diameter often increased from two to four times the usual amount as rapidly as elongation occurred. An improvement over the usual method of using the horizontal microscope for observation of the growth of seedlings is obtained by making the spacing marks very distinct and thin on one side or sometimes for special observation of young roots entirely around by means of a suitable revolving apparatus. The glass apparatus containing the marked seedling for observation should then be maintained at an absolutely constant temperaturs in order to avoid condensation. With a scale spacing of .05 mm. the readings taken can be made very

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exactly. The absence of strings or other attachments as is often the case in stem measurements is an advantage as even slight disturbances are apt to result in considerable growth alterations. By the proper adjustments the diminution in diameter may also be observed as well as occasionally a contraction in length which latter still awaits explanation in various respects. While a slight disturbance will affect the growth of the roots involving great care in their treatment, yet on the other hand it is interesting to note that the severe conditions, such as pressure, displacement of contents, and other changes from the normal which may surround them, may not be fatal nor even cause a cessation of growth. Before the elongation of roots and stems as well as any increase or decrease in diameter, as in the fungi and other small plants, can be accurately measured by means of the horizontal microscope.

For the measurement of stems the arc-indicator as first used by Sachs is unnecessarily complicated. The one later used by Pfeffer is better. I have devised a form in which the usual lever which magnifies the growth ten times is a rigid truss. The usual lever is transformed into a truss from the axis to the end over the arc. It is composed of steel and brass and, although very light, is very strong, and permits no sagging at the arc end, and is balanced by a weight where the plant is attached. The ordinary forms are very apt to show some drop at the arc end and this error is made more serious on account of the magnification of growth that is involved. The accuracy of this truss arc is indicated by actual measurements of the same plant where used and auxanometer readings. Great care is necessary in attaching the string or thread to the plant, for no matter how carefully this is done the rate of growth is unavoidably influenced to a degree by this treatment. It is advisable in this case as with the auxanometer to give special attention to the preparation of the thread, to use Nathansohn's method of attachment and to use as short a thread as is consistent with the working of the apparatus. The temperature and light conditions may be controlled as was used by Sachs, by means of halved cylinder carrying a thermometer. When in strong illumination an opening should be provided for the passage of air to control the inner temperature. By suitable arrangement the specimen and flower pot may be inclosed in a thermostat and thus the effect of temperature very closely studied. The diametrical growth may also be studied, under proper conditions, by using a square rectangular clear glass box around the plant. The disadvantage of the arc form of auxanometer is that only those periods of time which are observed show the growth which has occurred.

This difficulty is removed in the automatic auxanometers which have been constructed. A good many forms of such instruments have been made by different investigators, but the best one thus far made is the self-registering auxanometer as devised and constructed by Pfeffer. Different increments of time may be employed as desired or in accordance with the rapidity of growth of the plant used. When properly used this instrument is capable of very desirable accuracy, but this requires great precaution. Specially prepared and treated silk threads should be used and when these are adjusted to the plant and the machine, the first few hourly records of growth should be discarded, until the necessary adjustments of the parts concerned have been established. The value of the machine would be considerably enhanced if it were provided with light cone pulleys in place of the usual ones employed, although this is, in many cases, cared for by the provision for setting the clock for different intervals of time. I have supplied the apparatus with what has proved to be a useful feature. This consists of a rectangular box large enough to enclose the plant and connecting threads with all or part of the sides and top of glass. This arrangement allows direct observation at all times since illumination is provided for, and at the same time this box prevents the disturbing effects of currents or air. The box is so arranged that opaque sides may be used when it is desired to darken the plant. A darkened electric light bulb of suitable size is also contained in the box so that the plant is independent of the temperature outside. By thus raising or lowering the inside temperature by this means an exact method of the effect of temperature is possible. A slow stream of air of sufficient rapidity to effect a desirable change is possible by adjusting the glass lid to the box. Some hours before arranging the experiment the plant should be well watered, allowed to stand till the earth has ceased to settle and the pot then placed in a glass vessel of proper depth and its top covered with paraffined paper to prevent further loss of water except through the plant. Unless this latter precaution is followed, and the growth of the plant becomes slow, a reverse graph will be produced due to the fact that the slight settling of the soil in the pot due to drying may exceed the slight amount of growth as indicated by the graph. The common *Phaseolus multiflorus* is a suitable plant for experimentation as its stem tip affords a good surface for attachment, but plants with leafy stem tips when young should not be used. The method of thread attachment as employed by Nathansohn should be used. A magnification of growth of ten times may be obtained, which is sometimes too great for one hour periods so that the use of shorter time intervals are often necessary in the case of very rapidly growing plants. A study of 60 hourly growth records of *Phaseolus multiflorus* of 50 different specimens of this plant gave uniform results. Their growth averaged 1.6 mm. for the first accepted five hour records which was in daylight and 2.8 for the next ten hours which was during the night. The second day's growth of twelve hours when the plant was illuminated averaged .3 mm. for each hour and .5 mm. per hour during darkness. This bears out what plants usually do under conditions of illumination and darkness but in these experiments the temperature was accurately controlled which enabled a safe comparison, which might otherwise be annulled by the difference in temperature being too high during the day or too low for good growth at night. The records obtained by means of the autonomic auxanometer also agreed very closely with the hourly growth records which it was possible to observe and obtain by means of the arc-indicator, as I have constructed it. The unsupported arm lever type is not reliable for accurate measurements. Growth in thickness of the elongating region began early as indicated by the horizontal microscope before it was detectable otherwise and was far advanced by the end of the first 24 hours.

The magnetic crescograph of Bose is very sensitive and is capable of magnifying growth 10,000 times. The use of a thread attachment with this instrument also has its objections. Certain projection apparatus eliminates the use of any attachments to the plant and is capable under favorable conditions of magnifying growth thousands of times. Its use is, however, limited and photographic registration is necessary for undisturbed records of growth in plants.

Cinematography has been employed successfully for many growth measurements, and Cine-photomicrography is also useful in cell growth.

PRESERVATION OF DRY PLANT MATERIAL

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Material for plant study, as is often preserved in alcohol or other preservatives, to use for subsequent investigation, at times dries up entirely and is frequently then considered of no further value and is therefore generally thrown away. This is important since valuable and oftentimes irreplaceable material is lost. It is also at times a serious loss of time and much care and effort which may have been expended in fixing and preserving the material up to the point of dehydration of the alcohol used. It has been the writer's custom to bring the specimens gradually into 95 per cent alcohol and allow them to remain there until needed. It is inadvisable to allow bulky specimens to remain in alcohol of even 70 per cent, especially if there is a considerable quantity of them. The specimens should be separated from one another so that they will be completely surrounded by a large volume of alcohol, and this changed frequently as the process of dehydration slowly progresses. In the higher per cents of alcohol the specimens should always be left a longer time than in the lower per cents. Several days, at times and according to the nature of the material, is not too long to allow the specimens to remain in 70 per cent, and stronger per cents of alcohol even if the specimens are to be used at once, since it insures more gradual and more completely dehydration without damage to the material. Much of such material of plants which has dried out and generally supposed to be a total loss may be restored to a good condition if proper care is used as regards its structural features. In order to recover some plant material, that was of sufficient value, the writer has subjected the dried out parts of certain plants to a special treatment which has again rendered them available for certain studies from a structural standpoint. The plants used for this treatment were the stems of *Zea mays*, and *Cucurbita Pepo* and the leaves of *Iris versicolor*, *Iris cristata*, and *Sambucus canadensis* and the petioles of *Caladium bicolor*. All of these plants are of sufficient delicacy to allow of great shrinkage and distortion by complete desiccation. In addition to the above mentioned plants, branches from three to six millimeters in diameter of *Tilia americana* were also dried after having been in 95 per cent alcohol. Specimens dehydrated in 95 per cent alcohol dry quickly. The plants used here were kept dry for 30 days during which time the bark and wood of *Tilia americana* had partially separated. Soaking material in pure water only restores the natural conditions of the cell walls to a degree. The writer has resorted to the use of a strong vacuum pump. The specimens are first submerged in pure water, submerged by means of a glass weight and then placed under the glass receiver of the vacuum pump. The pump is then allowed to operate under as high a vacuum as possible, for different lengths of time according to the nature of the material. In some cases the pump was allowed to act 15 hours. For long periods of action of the pump it is advisable to mount as many specimens as possible under the receiving jar at one time. The strong action of the pump on the submerged specimen over a period of a few to many hours removes the air and allows the water to enter the tissues so that they generally resume their former appearance, in many cases, almost perfectly. It is a decided improvement over the method of simply allowing a set of tissues to soak in water. This method, of course, does not effect the cell contents, but applies to the readjustment of the cell walls and tissues. After such treatment the specimens must be carefully dehydrated in the usual way. The specimens may also be very effectively cleared during the action of the vacuum pump by observing the proper strength and length of time such clearing reagents as carbolic acid and chloral hydrate require. The addition of glycerine materially aids the clearness of the tissues if added to the water during the action of the pump. By the method outlined here valuable material may be restored as regards the form of cells and cell walls almost to its original condition so that the study of tissues is easily made.

ANATOMICAL STUDIES WITHIN THE GENUS HYDRANGEA

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Rehder (6) describes the members of the Saxifragaceae, of which there are about 75 genera with 700 species widely distributed in both hemispheres, as herbs, shrubs, or small trees. The leaves, he states, are alternate or opposite and usually without stipules. The flowers, which are five-merous, regular, and either hypogynous or perigynous, are either axillary or in terminal corymbs or occasionally in panicles. The fruit is either a several seeded capsule or berry.

The genus *Hydrangea* represents 35 species of deciduous, upright shrubs, excepting *H. petiolaris* which climbs by aerial roots. The leaves are opposite as a rule but often are whorled in *H. paniculata; H. quercifolia* is the only member of the genus having lobed leaves, which are also the largest found in the genus.

The species of *Hydrangea* are natives of North and South America and east Asia as far south as Java. The following species are native to North America: *arborescens*, New York to Iowa and southward to Florida and Louisana; *cinerea*, North Carolina and Tennessee to Georgia and Alabama; *quercifolia*, Florida and westward to Mississippi; and *radiata* in the Carolinas. From North China we have *Bretschneideri*; West China, *xanthoneura setchuenensis;* and *paniculata* and *petiolaris* from Japan and China.

LITERATURE

The work that has been published on the genus *Hydrangea* shows that very little has been done so far; however, numerous references are made relative to the value of certain species of *Hydrangea* in landscaping and gardening. Of the various species mentioned, *H. quercifolia* or the "Oak-leaved Hydrangea" as it is commonly called, seems to receive most attention in popular literature. This species is not only prominent because of its large panicles of flowers, Sargent says, but also for its beautiful habit of growth. In the South, which is the native habitat for this species, *quercifolia* often attains a height of fifteen feet. Almost as attractive as the flowers or the plant's growth are the large lobed leaves, which assume a beautiful red color in the fall.

In the Silva of North America reference is also made to the relative value of H. *petiolaris* as a climbing shrub. The flowers are not as attractive as those of other species of the group, but the plant is excellent as a cover for old walls, stones, etc.

Rehder (6) has published a detailed and useful account of the external features of the Hydrangeas. His descriptions have been very helpful in describing the general and external features of the group.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

He also gives the distribution and original habitats of the various species.

Solreder (7) collected and published the literature on the Saxifragaceae, and in it refers quite often to the genus *Hydrangea*. Holle (4) also published an account giving the anatomical features of the Saxifragaceae.

Engler and Prantl distinguish the American and Asiatic forms by means of the ovary and seeds. The Asiatic forms, they say, have half-superior ovaries and round or broadly-elliptic, unstriated seeds while the American forms have inferior ovaries with elliptic, longitudinally striated seeds.

The various keys noted in the literature have been based entirely on external features. The writer has undertaken this study to discover anatomical characteristics common to a species and its varieties, and if possible, to make keys using only anatomical differences.

ANATOMICAL FEATURES OF THE STEMS AND LEAVES OF *HYDRANGEA ARBORESCENS* AND VARIETIES *URTICIFOLIA* AND *GRANDIFLORA:*

PRIMARY TISSUES

Epidermis. The epidermises of this species and two varieties are very similar. As seen in surface view the cells are rectangular in each case although the cell cavities of the variety *urticifolia* are slightly larger than those of the species *aborescens* and variety *grandiflora*. The vertical diameter of an epidermal cell, which in most cases is the greater, measures .06 mm., while the tangential diameter is about .035 mm. and the radial diameter about .018 mm. Trichomes of the simple-clothing-hair type, which characteristically point upwards, are found on the younger portions of the stems, but the stem soon becomes glabrate. The trichomes of the species and its two varietiess are similar and about .16 mm. in length. As is characteristic of the genus, the trichomes are heavily encrusted with calcium carbonate.

Tannin bodies are found in the epidermis of the species and its varieties; and an especially large amount of tannin occurs in the epidermal cells of variety *urticifolia*.

A thin cuticle measuring .003 mm. in thickness is found on the epidermis of the younger stems. No cutinization is present.

Primary Cortex. The primary cortex has about the same thickness in the species and two varieties; in stems having a diameter of 5 mm. the primary cortices measure about .2 mm. in thickness in each case. The greater part of the cortex is taken up by the 6-7 cell layers of collenchyma.

The cortices of this group are almost identical. The collenchyma cells are rectangular as seen in cross section and have radial and tangential walls of about the same thickness. As seen in longitudinal sections, the cells of the collenchyma are rectangular in shape, have vertical diameters of .07 mm. and radial diameters of .025 mm. Since the radial walls are about as thick as the tangential walls the collenchyma is not crushed as early as we find it in other species of the genus.

The cortical parenchyma consisting of 3-4 layers of thin-walled cells contains a small amount of starch and a few crystal sacs filled with raphide crystals of calcium oxalate. The crystal sacs are prominent because of their relatively great size, becoming .055 mm. wide and about .08 mm. in vertical length.

Primary Xylem. The primary xylem of this species and its two varieties consists of 20-22 protoxylem points with the metaxylem exterior and filling in between the points to complete a vascular cylinder.

The protoxylem points, each consisting of 6-7 radial rows of tracheal tubes, are subtended by a lignified medullary sheath 2-3 cell layers thick. Between these radial rows of primordial tracheal tubes is quite a large amount of unlignified, thin-walled xylem parenchyma in which starch is found.

The metaxylem completing the vascular cylinder is very limited in radial extent, there being one to two layers of tracheal tubes and a very few scattered tracheids. Between the tracheal tubes is a small amount of xylem parenchyma containing a little stored starch.

In cross section the annular tubes measure .025 mm. and the slightly larger metaxylem tubes measure .035 mm. The length of an annular element is about .12 mm., while an element of a metaxylem tube is approximately .16 mm. long.

Primary Phloem. Since there is little difference between the primary and secondary phloem, the two are discussed together under the secondary tissues.

Pith. The unlignified pith in this group is quite an outstanding feature, since lignification of the pith is a common character of the genus as a whole.

As seen in longitudinal sections, the majority of pith cells are hexagonal. The radial diameter measuring .19 mm. is much greater than the vertical diameter which measures about .05 mm.

The pith is relatively large, measuring about 5 mm. in cross section in stems having diameters of about 7 mm.

Crystal sacs, similar to those found in the primary cortex, are commonly found in the pith of the younger stems. No reserve foods are found in the pith other than the starch commonly found stored in the medullary sheath.

SECONDARY TISSUES

Periderm. As in the majority of the species, the cork cambium is formed in the outermost part of the cortical parenchyma. The periderm measures about .17 mm. in the species *arborescens* and variety *urticifolia* while that formed in variety *grandiflora* measures approximately .23 mm.; in all three cases the stems measured about 5 mm. in cross section. The cork cells, which have undulated tangential walls, have radial diameters of .02 mm., tangential diameters of .03 mm., and vertical diameters of .04 mm.

The collenchymatous phelloderm varies in thickness from 3-5 cell layers. It is interesting to note that in variety *urticifolia* the phelloderm formed is thicker than the cork, the phelloderm measuring about .09 mm. and the cork about .07 mm.

An abundance of starch and protein are stored in the phelloderm.

Phloem. In cross section, the phloem, both primary and secondary, measures approximately .12 mm. radially. Quite an outstanding feature of this group is the unusual amount of starch stored in the parenchyma of the outer phloem region and almost as prominent as the stored starch is the protein found in the phloem tissues.

The few sieve tubes are rather large, measuring .03 mm. in cross section and the sieve tube elements have vertical diameters of .07 mm. The companion cells are made evident by the quantity of protein they contain. In cross section the companion cells are .02 mm. by .01 mm., and extend vertically approximately the length of a sieve tube element.

Secondary Xylem. Perhaps the most outstanding feature of the secondary xylem in this group is the great number of tracheids which are in definite radial rows. In these radial rows of tracheids is an occasional tracheal tube and on either side of the rows are xylem rays. Scattered wood fibers are sometimes found along the sides of tracheids. It is interesting to note that when wood fibers are found, the tracheids adjoining them are smaller than usual, suggesting that tracheid and fiber might have come from the same cambial initial.

Secondary tracheal tubes measure approximately .02 mm. in cross section, whereas the tubes of the metaxylem measure as much as .035 mm. across. However, the vertical diameter of a secondary tracheal tube element measures as much as .35 mm., which is more than twice the vertical diameter of a primary tracheal element.

In cross section an average-sized tracheid measures .02 mm. tangentially, .013 mm. radially and its length is about .06 mm. Wood fibers measure .01 mm. in cross section, with cavities half this breadth. The length of a wood fiber is approximately .9 mm.

An abundance of xylem parenchyma, the cells of which measure .02 mm. in cross section and have vertical diameters of .07 mm., contains a large amount of reserve starch.

Both uniseriate and multiseriate rays occur in this group. The multiseriate rays, 3-4 cells wide, are found adjoining the protoxylem points and extend to the outer edge of the phloem. The uniseriate rays as stated above, are found on either side of the radial rows of tracheids; these, too, extend to the outer edge of the phloem.

An average-sized cell of the ray (those nearer the lower and upper extremities have greater vertical diameters) measures .019 mm. in cross section and .06 mm. vertically.

As in the xylem parenchyma, much starch is stored in the rays.

LEAVES

General Features. The leaves of this group are very similar, but vary in minor features. The leaves of variety *urticifolia* are more sharply acuminate and the tips of the leaves of *arborescens* are less sharp and sometimes rounded. The leaves of *arborescens*, which are the largest, are from 6-20 cm. long, while the leaves of *urticifolia* are from 4-10 cm. long. The leaves of *arborescens* and variety *urticifolia* are somewhat crenate, and the bases round to cordate. The leaves are glabrous above but slightly pubescent on the under surface along the veins; they are of uniform texture and average about .21 mm. in thickness.

Epidermis. The lateral walls of the upper epidermal cells of *arborescens* are slightly undulated, a feature lacking in the varieties. (Fig. 31). The cells as seen from the surface are irregular in shape, averaging .055 mm. in diameter. The cells of the lower epidermis are similar (Figs. 27, 28, 34); however, those of variety *grandiflora* are slightly larger than those of *arborescens* and variety *urticifolia*. The trichomes found along the veins on the lower surface have quite thick walls which are somewhat roughened by encrustation with calcium carbonate. A cuticle measuring .001 mm. in thickness is found on the upper epidermis, but cutinization is absent.

Mesophyll. One layer of palisade cells .04 mm. in length and .017 mm. in cross section occupies about one third the mesophyll volume. The cells of the spongy parenchyma are irregular with large intercellular spaces between them. Large crystal sacs are commonly found in the spongy layer.

Midrib. The midribs are ovate as seen in cross section and project slightly above the leaf surface. The projection is composed largely of collenchyma, which is also found on the lower surface of the midrib. The vascular tissue is in the form of an arc which is surrounded by thin-walled parenchyma cells. (Figs. 19, 21, 22.)

Margins. The margin of *arborescens* species is the only one studied which is incurved. Collenchyma is also lacking in the margin of this species. The normal leaf structure of variety *urticifolia* continues to within .17 mm. of the margin where collenchyma is found. Collenchyma extending .3 mm. from the margin is found in variety *grandiflora* and here the outer walls of the epidermal cells are slightly thicker than farther back in the leaf surface. (Figs. 7, 8, 9.)

Petioles. The petioles are relatively large as seen in cross section, measuring from 2-2.5 mm. from the lower to the upper surface and 2-3 mm. in breadth. Three vascular bundles enter the petioles but they soon divide and redivide so that midway of the petiole there are 11-12 small bundles arranged in a semicircle. Near the leaf blade the bundles fuse to form a vascular arc which continues into the midrib. Three to four cell layers of thick-walled collenchyma are found below the epidermis. The vascular tissues are surrounded by thin-walled parenchyma cells which contain tannin, and among which are crystal sacs filled with crystals of calcium oxalate.

Venation. The midrib passes upward into the leaf apex; from the midrib branch veins which pass outward and upward along the margin. The veinlet meshes are relatively large, with a frequency of from 2 to 3 meshes per sq. mm. Free vein endings occur only in the larger meshes where from 2-3 are usually found. (Figs. 36, 40, 41.)

HYDRANGEA BRETSCHNEIDERI AND VARIETIES *LANCIFOLIA* AND *GLABRESCENS*:

PRIMARY TISSUES

Epidermis. The epidermal cells of the stem of this species and its two varieties are very much alike. As seen in surface view the cells are so very irregular that it is difficult to distinguish the tangential from the longitudinal diameters. The longer diameter of an average-sized cell is .04 mm. and the shorter diameter about .02 mm. (Figs. 16, 17, 18.)

The trichomes found on the young stems are very interesting, there being trichomes of the simple-clothing-hair type and also longer ligulate ones in great abundance. We would expect to find fewer trichomes on variety *glabrescens;* however, from the material I have used in my study I was not able to note an appreciable difference in size or numbers.

As in the species *arborescens*, the trichomes of the simple clothing-hair type are heavily encrusted with calcium carbonate; however, the ligulate trichomes show very little of such encrustation, although we do find an occasional projection of the cuticle from the cell wall.

The simple clothing-hair type of trichome measures approximately .35 mm. in length, where as those of the ligulate type are much longer, exceeding 2 mm. in some cases.

Primary Cortex. Rehder describes *Bretschneideri* as having "chestnut-brown bark peeling off in thin flakes." In the youngest material which I studied, I found this distinctive brown color; however, I find the dark-brown color due to the dead epidermis and collenchyma tissues. The cortex of a one-year old stem measuring 2 mm. in cross section has a thickness of .1 mm.; of this cortex the stretched, dead collenchyma occupies about .06 mm. The cortical parenchyma, which contains a few crystal sacs, measures about .04 mm. in thickness.

Because of the early formation of internal cork, the cortical tissues soon die, and become crushed, making it impossible to give the dimensions of the individual cells at this time.

Primary Xylem. The primary xylem is about the same in the species and two varieties, there being from 16-20 protoxylem points at the second internode of the current year's growth.

The tracheal tubes of the protoxylem in the species and its two varieties are in definite radial rows as in *arborescens*. Between the radial rows of tracheal tubes is a large amount of unlignified wood parenchyma containing much starch.

Around each protoxylem point is a partially lignified bundle sheath, slightly thicker than the sheath found in the varieties of *arborescens*. In this thick-walled bundle sheath is found a large quantity of oil, an especially large amount being found in *Bretschneideri* species.

In cross section the tracheal tubes of the protoxylem are approximately .02 mm., the tangential and the radial diameters being approximately the same. The vertical diameter of the tracheal elements is about .3 mm.

Metaxylem. Very little metaxylem is formed exterior to the protoxylem; however, the protoxylem points are connected by the metaxylem. A few thick-walled fibers are found adjoining the tracheal elements of the metaxylem. The tracheal elements of the metaxylem are very similar to those of the second xylem and measure .03 mm. in cross section and have vertical diameters of .09 mm.

Pith. The pith of *Bretschneideri* species and its varieties is lignified, whereas that of *arborescens* and its varieties showed no lignification.

There are very few crystal sacs in the pith of *Bretschneideri* and none were found in the pith of the two varieties.

An outstanding characteristic of the pith of the species *Bretschneideri* and its varieties is the large amount of oil stored in the pith; especially was this noticeable in variety *glabrescens*.

SECONDARY TISSUES

Periderm. One of the most outstanding features of this group is the early formation of a phellogen and the large amount of cork formed. In the species and two varieties the phellogen is formed by the innermost row of cortical parenchyma. In the table below are given the number of rows of cork cells, the thickness of the periderm, stem, etc.

	Thickness of stems.	Rows of cork cells.	Thickness of phelloderm	Thickness of periderm
H. Bretschneideri	2 mm.	11-12	.08 mm.	.32 mm.
Var. *lancifolia*...	2 mm.	12-13	.06 mm.	.24 mm.
Var. *glabrescens*.	5 mm.	14-15	.1 mm.	.4 mm.

The cell walls of the parenchymatous phelloderm are slightly thickened. Schizogenous intercellular spaces are very common in the phelloderm; especially large spaces are found in the variety *glabrescens*.

A large amount of starch is stored in the pheloderms of this group; variety *lancifolia* has the least amount of starch but perhaps a little more protein. Very little oil is found in the pheloderm of the two varieties but quite a large amount was noticed in that tissue of *Bretschneideri* species.

Phloem. The phloem in the species and its two varieties show little differences. Little phloem is formed in any of the species studied, but there are no indications of the phloem being crushed in a two-year-old stem.

The phloem measures approximately .07 mm. in thickness. Sieve tubes measure about .0275 mm. in cross section and the vertical diameters of the elements average .06 mm. The companion cells, which are slightly smaller than the sieve tubes in cross section, measure .02 by .01 mm. but may have vertical diameters of .06 to .08 mm.

In the phloem of *Bretschneideri* a great amount of oil is stored, but very little is found in the varieties. The amount of protein in the phloem is about the same in the species and varieties.

Secondary Xylem. The secondary xylem shows no great differences from that described for *arborescens*. There is a slight difference in the amount of secondary xylem formed in this group, which may be caused by slightly more favorable growing conditions.

The medullary rays are either uniseriate or biseriate. Those found in *Bretschneideri* species are mostly biseriate. The rays vary from 6 to 12 cells in depth and extend from .3 mm. to .48 mm. vertically. Individual cells of the rays are approximately .03-.04 mm. vertically and .03 mm. radially.

Starch is stored in all the rays of this group; an exceptionally large amount being found in the primary rays of variety *glabrescens*. Oil is found in the rays of *Bretschneideri* only.

LEAVES

In discussing the leaves, I shall describe the leaves of *Bretschneideri* species and then point out how the varieties differ from the species.

General Features. The leaves of *Bretschneideri* are 7-12 cm. long, elliptic to oblong-ovate and have serrate margins. The apices are acute to acuminate and the bases cuneate. The leaves are glabrous above, but villous beneath. The leaf blade has a thickness of about .28 mm. and the petioles, which are not winged, are from 1-3 cm. long.

The leaves of variety *glabrescens* are smaller, being from 4-10 cm. long, more elliptic, more coarsely serrate and sparingly pubescent beneath.

As the name of the variety suggests, the leaves of *lancifolia* are lanceolate and have serrate margins. Their lower surfaces are covered with short, fine trichomes which are more numerous and finer than those found on the variety *glabrescens* or the species. The leaves of *lancifolia* are from 10-20 cm. long.

Epidermis. As seen from the surface, the leaf epidermises of this group are very much alike, the cells being irregular in outline and variable in size, but those of the lower epidermises are distinctly smaller than those of the upper. The cells of the upper epidermises vary from .05-.06 mm. in diameter, while those of the lower epidermis average .04 mm. The radial diameters average .03 mm. (Figs. 26, 28, 29, 30, 32, 33.)

The trichomes found on the lower surface of the leaves vary greatly, both in size and in numbers. Those found on the leaves of *Bretschneideri* measure 1.5 mm. in length and are also quite numerous. The trichomes are rather sparse on leaves of variety *glabrescens* and are about the same size as those of *Bretschneideri* species. Trichomes occur most abundantly on the leaves of variety *lancifolia*, but they are smaller and finer than those found on the other members of this group, averaging only 1 mm. in length. In all cases the trichomes are encrusted with calcium carbonate.

A thin cuticle is found mainly on the upper surface, with only traces on the lower. Very little difference in the thickness of the outer and inner walls of the epidermal cells was noted.

A count of the stomata shows that there are from 200-275 per sq. mm.

Mesophyll. The number of palisade cells varies from 5,000 per sp. mm. in *glaborescens* to 6,210 in *Bretschneideri*. They are .1-.12 mm. long and about .02 mm. wide and occupy about one half the mesophyll volume. The cells of the spongy parenchyma as in *arborescens* are very irregular and have large intercellular spaces between them.

Crystal sacs lying parallel to the leaf surface and averaging .16 mm. in length are very common in the spongy mesophyll, and are quite outstanding in bleached leaves.

Leaf Margins. As seen in cross section the leaf margins are very blunt. The margin of *Bretschneideri* differs from the other two (Figs. 10, 11, 12) by having two rows of palisade cells while back from the margin there is only one row.

Next to the margin is a small amount of collenchyma, and here the outer and inner walls of the epidermal cells are thicker than those farther in from the margin. The cuticle is thicker at the margin and is somewhat serrate. It measures .003 in thickness.

Midribs. The midribs of the species and varieties show a marked similarity when seen in cross section. (Figs. 20, 23, 24.) The midribs of *Bretschneideri* species and variety *glabrescens* are the larger, measuring 1.5 mm. in thickness while the midrib of variety *lancifolia* measures about 1 mm. in thickness.

In each case there is a slight projection of the midrib above the leaf blade composed of 4-5 cell layers of collenchyma extending entirely around the midrib. In the ground tissue around the vascular arc is found a notable amount of tannin. The vascular tissues compose a concentric bundle, the phloem entirely surrounding the xylem.

Petiole. Other than the petiole of variety *lancifolia* being slightly smaller than those of *Bretschneideri* and variety *glabrescens*, there is little difference in the petioles of this group. In cross section they are ovate wing-like projections at either side of the upper surface.

Beneath the epidermis are 4-5 cell layers of collenchyma cells with prominent walls which measure as much as .03 mm. in thickness.

The ground parenchyma of rather loose structure contains numerous crystal sacs and quite a large amount of tannin. At the base of the petioles are three bundles, one below the middle and one above either side of the lower. As the bundles pass through the petiole they gradually fuse to form a concentric bundle, the phloem surrounding the xylem as in the midrib mentioned above.

Venation. The leaves of this group have prominent midribs from the base to the apex. From the midrib lateral veins are alternately given off which pass outward and upward along the margin. In bleached leaves, at a distance of 2 mm. from the apex we find the midrib and two lateral veins along the margin. As is characteristic of all the leaves, the meshes are relatively large, there being an average of 4.5 meshes and 4 free vein endings per sq. mm. (Figs. 37, 38, 39.)

SUMMARY

This brief study shows that there is a close anatomical relation between the species and their varieties, and also that there are anatomical differences among the various species.

As a result of this study, I have noted several outstanding differences.

1. The pith of *Bretschneideri* and varieties *lancifolia* and *glabrescens* is lignified, whereas the pith of *arborescens* and varieties *grandiflora* and *urticifolia* shows no lignification.
2. Oil, as evidenced by Sudan III, is present in large amounts in the *Bretschneideri* group but was absent in the other group studied.
3. Multiseriate rays are common in *arborescens* and its varieties but are not found in the other species mentioned.
4. Cork is formed earlier and more abundantly in *Bretschneideri* and its varieties.
5. The stem epidermises of *Bretschneideri* and its varieties have cells that are elongated and somewhat rectangular but those of *arborescens* and its varieties are very irregular and with little differences in the tangential and vertical diameters.
6. On the stem epidermises of *Bretschneideri* and its varieties are found two kinds of trichomes, those of the simple clothing-hair type and also longer ones of the ligulate type.
7. The phelloderm of *arborescens* and its varieties is also different from that of *Bretschneideri* by being collenchymatous while that of the *Bretschneideri* is parenchymatous.
8. Crystal sacs are common in the pith of the *arborescens* group but are lacking in the *Bretschneideri* group.

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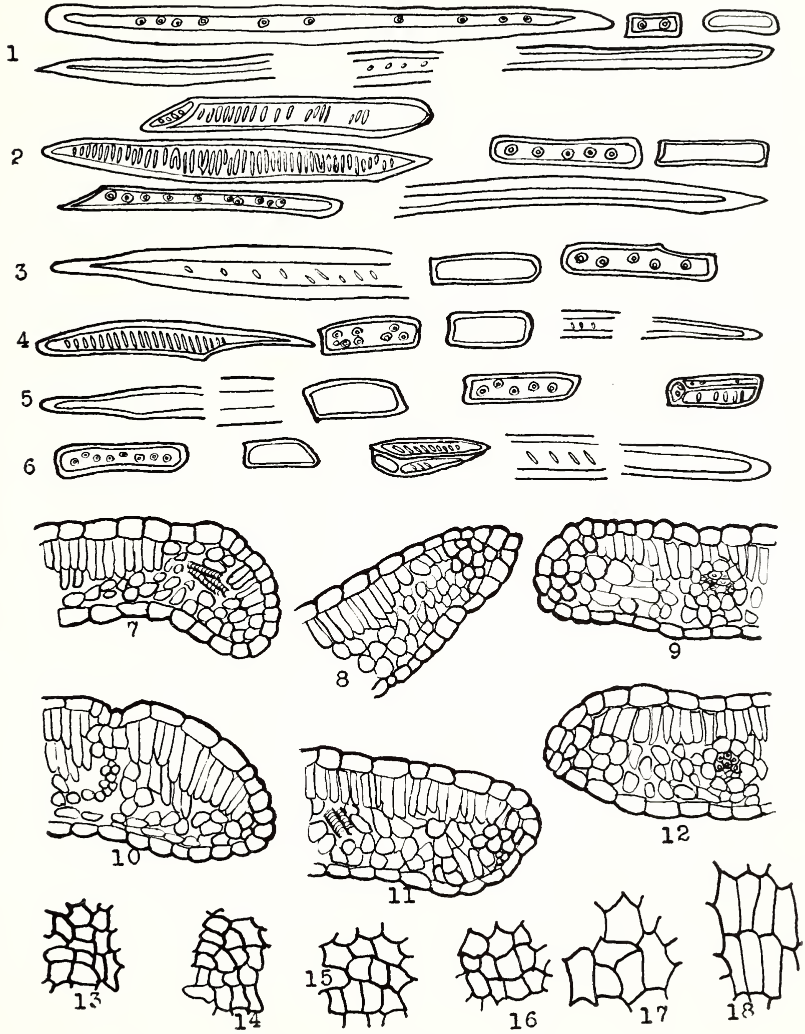

PLATE I

Figures 1-6, drawings of the xylem elements. x 162

Fig. 1. *Hydrangea arborescens*
Fig. 2. *Hydrangea arborescens grandiflora*
Fig. 3. *Hydrangea arborescens urticifolia*
Fig. 4. *Hydrangea Bretschneideri*
Fig. 5. *Hydrangea Bretschneideri glabrescens*
Fig. 6. *Hydrangea Bretschneideri lancifolia*

Figures 7-12, drawings of the leaf margins. x 125

Fig. 7. *Hydrangea arborescens*
Fig. 8. *Hydrangea arborescens grandiflora*
Fig. 9. *Hydrangea arborescens urticifolia*
Fig. 10. *Hydrangea Bretschneideri*
Fig. 11. *Hydrangea Bretschneideri glabrescens*
Fig. 12. *Hydrangea Bretschneideri lancifolia*

Figures 13-18, drawings of stem epidermises. x 162

Fig. 13. *Hydrangea arborescens*
Fig. 14. *Hydrangea arborescens grandiflora*
Fig. 15. *Hydrangea arborescens urticifolia*
Fig. 16. *Hydrangea Bretschneideri glabrescens*
Fig. 17. *Hydrangea Bretschneideri lancifolia*
Fig. 18. *Hydrangea Bretschneideri*

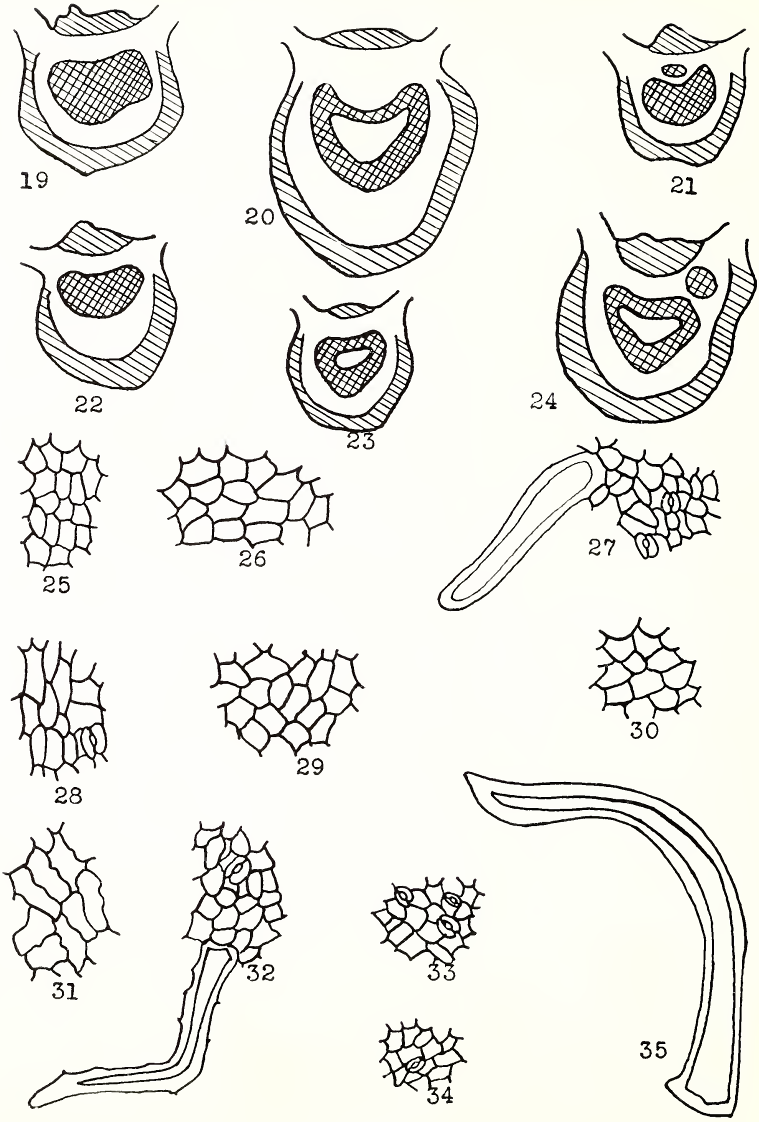

PLATE II

Figures 19-24, drawings of cross sections of the midribs. (Vascular tissues solid; collenchyma shaded.) x 28

Fig. 19. *Hydrangea arborescens*
Fig. 20. *Hydrangea Bretschneideri glabrescens*
Fig. 21. *Hydrangea arborescens urticifolia*
Fig. 22. *Hydrangea arborescens grandiflora*
Fig. 23. *Hydrangea Bretschneideri lancifolia*
Fig. 24. *Hydrangea Bretschneideri*

Figures 25-35, drawings of the upper and lower epidermises. x 182

Fig. 25. Upper epidermis of *H. arborescens grandiflora*
Fig. 26. Upper epidermis of *H. Bretschneideri*
Fig. 27. Lower epidermis of *H. arborescens grandiflora*
Fig. 28. Lower epidermis of *H. Bretschneideri lancifolia*
Fig. 29. Upper epidermis of *H. Bretschneideri lancifolia*
Fig. 30. Upper epidermis of *H. Bretschneideri glabrescens*
Fig. 31. Upper epidermis of *H. arborescens*
Fig. 32. Lower epidermis of *H. Bretschneideri glabrescens*
Fig. 33. Lower epidermis of *H Bretschneideri glabrescens*
Fig. 34. Lower epidermis of *H. arborescens*
Fig. 35. Trichome on stem of *H. Bretschneideri* x 182

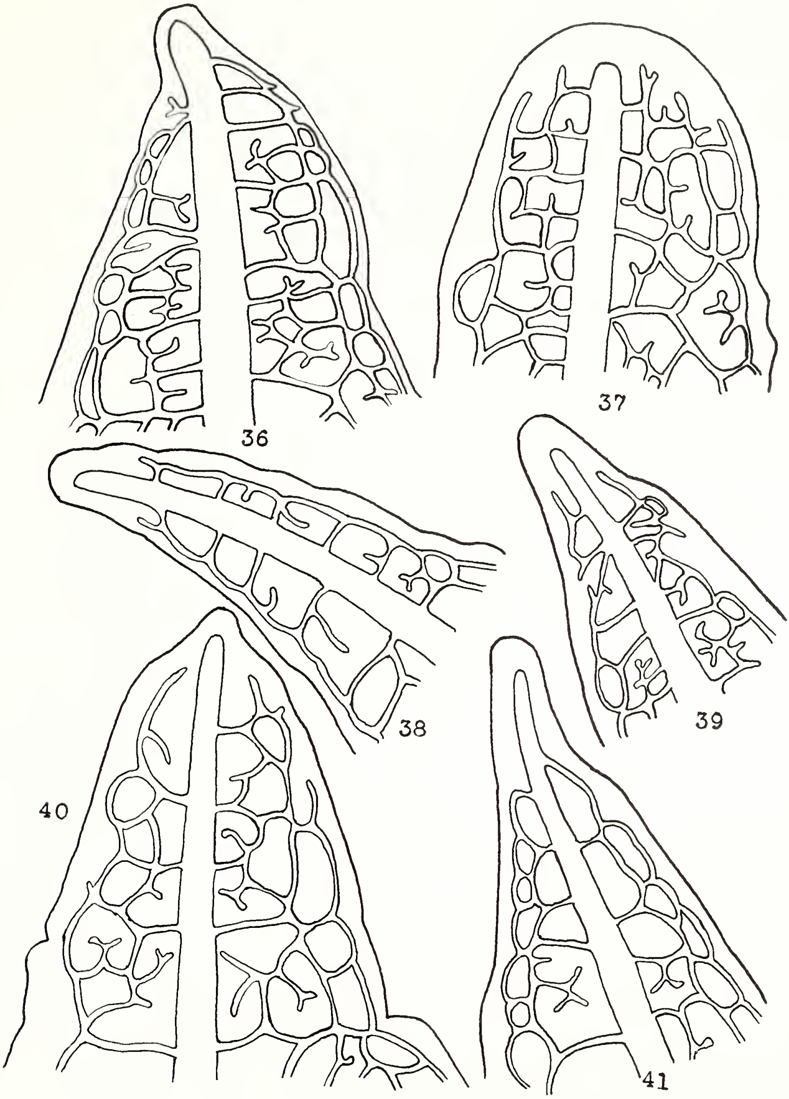

PLATE III

Figures 36-41, venation drawings of leaf tips. x 28

Fig. 36. *Hydrangea arborescens*
Fig. 37. *Hydrangea Bretschneideri*
Fig. 38. *Hydrangea Bretschneideri glabrescens*
Fig. 39. *Hydrangea Bretschneideri lancifolia*
Fig. 40. *Hydrangea arborescens grandiflora*
Fig. 41. *Hydrangea arborescens urticifolia*

PLANTS OF SPRING MILL STATE PARK, LAWRENCE COUNTY, INDIANA: I—FERNS

STANLEY A. CAIN, Indiana University

For about four weeks during August and September, 1931, the writer was permitted to botanize at Spring Mill State Park, Lawrence County, Indiana. The relatively new park consists of over one thousand acres, largely wooded, but with some abandoned fields. The residual soils are derived from the Mitchell limestone. The topography is typical karst, with literally one sinkhole after another. Hamer's Creek, arising from a cave near the more than century old village, which is being reconstructed, joins a system of surface drainage, with, however, very little marshy ground. Generally speaking, the fern flora is not very rich. Twenty-one species are listed as observed and collected. Five other species, fairly common, most certainly should be found within the park area. They are: *Pteris aquilina* L., *Aspidium noveboracense* (L.) Sw., *Aspidium spinulosum* var. *intermedium* (Muhl.) S. C. Eaton, *Cystopteris fragilis* (L.) Bernh., and *Ophioglossum vulgatum* L.

The appearance of short, local lists such as the ones in this series are hardly justified except by their utility, for example, in connection with nature guiding carried on by the Indiana Department of Conservation under the guidance of Mr. Sidney Esten. The writer wishes to thank the Department of Conservation for courtesies extended in connection with this work. Herbarium sheets are deposited at Indiana University and with the Department of Conservation. Nomenclature according to Gray's Manual, 7th ed.

POLYPODIACEAE

Phegopteris hexagonoptera (Michx.) Fee. Beech fern, in good fruit, Aug. 21, 1931. Common in woods. No. 75.

Adiantum pedatum L. Maidenhair fern, in good fruit, Aug. 21, 1931. Common in woods and thickets. No. 76.

Pellaea atropurpurea (L.) Link. Purple Cliffbrake, in good fruit, Aug. 25, 1931. Scarce on rocks (limestone) above the mouth of Donaldson's Cave. No. 108.

Asplenium platyneuron (L.) Oakes. Spleenwort, past fruit, Aug. 20, 1931. Common near the far end of trail 2, under *Juniperus virginiana* on limestone rocks with *Woodsia obtusa*. The soil frequently becomes very dry. No. 64.

Asplenium angustifolium Michx. Narrowleaved Spleenwort, in good fruit, Aug. 20, 1931, along the west end of trail 2. Sterile fronds are much more abundant than fertile fronds. No. 56.

Asplenium acrostichoides Sw. Silver Spleenwort, in good fruit, Aug. 20, 1931. Rich woods. No. 54.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

Asplenium Filix-foemina (L.) Bernh. According to Gray's Manual, 7th Ed. The true identity of this plant, according to more recent botany, has not been determined by the writer. Lady fern, in good fruit, Aug. 27, 1931. In woods, scarce. No. 148.

Camptosorus rhizophyllus (L.) Link. Walking fern, past the fruiting prime, Aug. 21, 1931. Limestone rocks and cliffs, common. No. 77.

Polystichum acrostichoides (Michx.) Schott. Christmas fern, past the fruiting prime, Aug. 20, 1931. In woods, very common. No. 55.

Polystichum acrostichoides (Michx.) Schott. var. *Schweinitzii* (Beck) Small. Incised Christmas fern. The species shows all degrees of serration to typical incised plants recognized as the variety. With the species.

Aspidium marginale (L.) Sw. Marginal Shield fern. This species was not collected in 1931, but the writer and Dr. Friesner of Butler University found it within the park area in 1921. It used to grow near the mouth of Donaldson's cave and has probably been eliminated by the spread of *Vinca minor* L. which has escaped from Donaldson's home site and the monument to Wilson, nearby. Although the Periwinkle makes a handsome appearance it is a very serious menace to the native herbs.

Aspidium Goldianum Hook. Goldie's Shield fern was also collected by Dr. Friesner and the writer in 1921. It was not observed in 1931.

Cystopteris bulbifera (L.) Bernh. Bulb fern, indusia were in poor shape but the bulbs were plentiful, Aug. 21, 1931. Very common on limestone rocks and hillsides where the soil is thin, in woods. No. 78. Some of the low soil forms were difficult to distinguish from *C. fragilis* (L.) Bernh. in the absence of bulbs.

Woodsia obtusa (Spreng.) Torr. This Woodsia is especially common under Juniper on limestone rocks. Fruit over-ripe, Aug. 20, 1931. No. 63.

Onoclea sensibilis L. Sensitive fern, not fruiting, Sept. 4, 1931. In a sink hole in the virgin forest north of the road near the largest yellow poplar in the park. No. 178.

OSMUNDACEAE

Osmunda claytoniana L. Interrupted fern, not fruiting, Sept. 4, 1931. In second-growth oak on hill-top. No. 177.

OPHIOGLOSSACEAE

Botrychium virginianum (L.) Sw. Rattlesnake fern, past fruiting, Aug. 20, 1931. Common in woods. No. 65.

Botrychium obliquum Muhl. Grape fern, not in fruit, Sept. 4, 1931. Rare in rich woods. No. 175.

Botrychium obliquum Muhl. var. *dissectum* (Spreng.) Clute. Dissected Grape fern, not in fruit, Sept. 4, 1931. Rare in virgin forest. No. 176.

EQUISETACEAE

Equisetum arvense L. Common Horsetail, sterile stems only, Aug. 26, 1931. Hamer's Creek. No. 123.

Equisetum hyemale L. Scouring Rush, not in fruit, Aug. 26, 1931. Common along B. & O. R. R. No. 143.

PLANTS OF SPRING MILL STATE PARK, LAWRENCE COUNTY, INDIANA: II—TREES, SHRUBS AND WOODY VINES

STANLEY A. CAIN, Indiana University

The nomenclature of the following list is in accord with that of Sudworth in his "Check List" of the Forest Trees of the United States" 1927, and Rehder's "Manual of Cultivated Trees and Shrubs," 1927. It is the writer's pleasure to thank Mr. Charles C. Deam of Bluffton, Indiana, for corrections and valuable suggestions. One hundred and nine woody species, of which all but eight are native, are listed from an area of a little over one thousand acres. Seventy-one are trees, two of which are escaped from cultivation (Pinus *virginiana* and *Ailanthus*) and 38 are shrubs, two of which are escaped (Vinca and Lonicera japonica). Since the collections were made in late summer when none were in flower it is possible that some changes in the list will have to be made. Some species will undoubtedly be added to the list as this new Park becomes better known. In addition to possible species in the genera Salix, Rubus, and Crataegus the following species are to be looked for: *Quercus bicolor* Willd. Swamp White Oak, *Amelanchier canadensis* (L.) Med. Serviceberry, *Gymnocladus dioicus* (L.) Koch. Coffeetree, *Robinia pseudoacacia* L. Black Locust, *Aesculus glabra* Willd. Ohio Buckeye, *Fraxinus quadrangulata* Michx. Blue Ash, *F. nigra* Marsh. Black Ash, *Alnus rugosa* (DuRoi) Spreng. Alder, *Rosa palustris* Marsh. Swamp Rose, *Rhus canadensis* Marsh. Fragrant Sumach (at Clifty Cave, Orange County) and *Cephalanthus occidentalis* L. Buttonbush. Sheets of the following species and varieties are deposited in the herbarium of Indiana University, Bloomington, and with the Department of Conservation, Indianapolis. For convenience the list is alphabetical.

**Abies alba* Mill. Silver Fir. Planted at the village.

Acer negundo L. Boxelder Maple, infrequent, Mill Creek.

A. nigrum F. A. Michx. Black Maple, Aug. 19, 1931. Less common than the preceding. No. 45.

A. rubrum L. Red Maple, Aug. 19, 1931. Abundant, especially younger stages, in woods. No. 27.

**A. saccharinum* L. Silver Maple, Aug. 26, 1931. Planted in Hamer's Cemetery. Should be found wild. No. 129.

A. saccharum Marsh. Sugar Maple, Aug. 19, 1931. Abundant in woods. No. 28.

A. saccharum rugelii (Pax.) Rehder. Sugar Maple, Aug. 29, 1931, good fruit. Woods near Upper Twin Cave. Leaves broader than long, pubescent beneath, smooth on the petioles and with three main attenuated lobes. This variety seems abundant and frequently well-marked from the Sycamore Creek region, Morgan County, southward. Common outside the Park in Lawrence and Orange counties. No. 173.

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* Means, planted.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

†*Ailanthus altissima* (Miller) Swingle. Ailanthus, Aug. 29, 1931. Escaped near Donaldson's Cave.

Amelanchier laevis Wiegand. Serviceberry, Aug. 25, 1931. This smooth species is found on the steep slopes above Donaldson's Cave and in the virgin forest. No. 102.

Ampelopsis cordata Michx. Heartleaf Ampelopsis, Aug. 27, 1931. Usually near streams but here along the railroad. No. 166.

Ascyrum hypericoides L. St. Andrews' Cross, Sept. 22, 1931. Open oak woods near Upper Twin Cave. No. 273.

Asimina triloba (L.) Dunal. Papaw, Aug. 20, 1931. Occasional in the virgin forest, sometimes in thickets. No. 58.

Benzoin aestivale (L.) Nees. Spice Bush, Aug. 20, 1931. Common undershrub in the richer woods. No. 59.

Campsis radicans (L.) Seemann. Trumpet-Creeper, Aug. 24, 1931. In open places. No. 87.

Carpinus caroliniana Walt. Blue Beech, Aug. 19, 1931. Very common small tree in climax woods. No. 43.

Carya (see *Hicoria*).

Ceanothus americanus L. New Jersey Tea, Aug. 27, 1931. Fields and open woods, fairly common. No. 167.

Celastrus scandens L. Bittersweet, Aug. 19, 1931. Common in open woods and especially along fences and the railroad. No. 33.

Celtis occidentalis L. Hackberry, Aug. 27, 1931. Woods west of the orchard, not frequent. No. 150.

C. pumila (Muhl.) Pursh. Dwarf Hackberry, Aug. 19, 1931. This very interesting tree (See C. C. Deam, "Trees of Indiana," pg. 148) is common on dry hillsides in open woods but is also found in the virgin forest. No. 38.

Cercis canadensis L. Redbud, in open places, Sept. 4, 1931. No. 189.

Clematis viorna L. Clematis, Aug. 20, 1931, in good fruit. This species is considered sufficiently woody to be included. It is the writer's opinion that as a general practice it is well to include such plants as Clematis, Mitchella, Gaultheria, Menispermum, etc., in woody lists as well as in herbaceous lists so that students can find them either place. No. 69.

Cornus alternifolia L. f. Blue Dogwood, Aug. 19, 1931. Frequent in deep cool ravines, as near Donaldson's Cave. No. 44.

C. asperifolia Michx. Roughleaf Dogwood, Aug. 20, 1931. Common in open woods and thickets. No. 70.

C. florida L. Dogwood, Aug. 24, 1931. Most abundant of small trees in the virgin forest and common elsewhere. No. 88.

Corylus americana Walt. American Hazel, Aug. 19, 1931. Common in thickets, along fences, etc., in good fruit. Nos. 34 and 57.

Crataegus crus-galli L. Cockspur Thorn, Aug. 25, 1931. This species is one of the few which can be identified with any surety without both flowers and fruits. Frequent in old fields and at the edge of woods. No. 112.

C. margarette Ashe. Aug. 25, 1931. Identification tentative in the absence of fruit and flowers. Old field. No. 114.

C. succulenta Link. Fleshy Hawthorn, Aug. 25, 1931. Good fruit, and the pitted character of the seeds fit the description well. Identification tentative, however, in the absence of flowers. In old field with

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† Means, escaped from plantings, propagating spontaneously.

Silphium, Physostegia, Andropogon, etc., above Donaldson's Cave. No. 113.

Diospyros virginiana L. Persimmon, Aug. 25, 1931. Very common in old fields, a weed tree. There are several variants which deserve study. No. 118.

Evonymus atropurpurea Jacq. Wahoo, Aug. 19, 1931. Fruit ripe the latter part of the month. Common. No. 47.

E. obovatus Nutt. Trailing Wahoo, Aug. 21, 1931. Local under heavy shade, forming dense mats. No. 73.

Fagus grandifolia Ehrh. Beech, Aug. 24, 1931. Frequent member of all mesophytic woods, sometimes forming almost pure stands, as north of Hamers' Cemetery on the slopes to Mill Creek. No. 86.

Fraxinus americana L. White Ash, Aug. 19, 1931. Common in woods. No. 36.

F. pennsylvanica Marsh. Red Ash, Sept. 28, 1931. This species with pubescent twigs is like the green ash in many other respects. Common in woods. Nos. 62 and 239.

F. pennsylvanica var. *lanceolata* (Bork.) Sargent. Green Ash, Sept. 29, 1931. Apparently common. In the absence of fruit the species of Fraxinus are frequently hard to distinguish. Characteristic plants of green ash have flat-topped leaf scars with "ears," while the white ash leaf scar is concave topped, yet many plants are indefinte as to these characters, as well as matters of pubescence, leaf color, stoutness, etc. No. 240.

Gleditsia triacanthos L. Honey Locust, not collected.

G. triacanthos inermis Willd. Thornless Honey Locust, Aug. 27, 1931. On a hillside with oaks. One tree of this variety was over one foot d. b. h. and absolutely without thorns. The variety, however, was intermingled with the species and the character showed no intergradation. Hillside northeast of the village. No. 158. Deam writes "This form is supposed to be restricted to the Missouri area."

Hamamelis virginiana L. Witch-hazel. Not collected.

Hicoria cordiformis (Wang.) Britton. Bitternut Hickory, Sept. 29, 1931, in good fruit. Frequent in woods and openings. Nos. 32 and 241.

H. glabra (Miller) Sweet. Pignut Hickory, Aug. 20, 1931. Upland woods, even in the virgin forest, but especially in old fields where it grows well along with Sassafras and Persimmon. Good crop of the characteristic fig-shaped fruit. No. 51.

H. laciniosa (Michx. f.) Sargent. Bigleaf Shagbark Hickory. Aug. 25, 1931. Scattered in woods. No. 99.

H. ovata (Mill.) Britton. Shagbark Hickory, Aug. 27, 1931. This and the preceding were seldom found fruiting. No. 160.

Hydrangea arborescens L. Hydrangea, Aug. 25, 1931. Fairly common in ravines and near streams. No. 107.

Juglans cinerea L. Butternut, Sept. 4, 1931. Common along streams. No. 191.

J. nigra L. Black Walnut, Sept. 4, 1931. Infrequent, although there are a few trees of large size in the virgin forest. No. 190.

Juniperus virginiana L. Eastern Red Cedar, Aug. 19, 1931. Frequent in old fields. Forms a woods on limestone bluffs in the northeastern part of the Park. No. 30.

Liriodendron tulipifera L. Tulip Tree, Aug. 25, 1931. The largest trees of the virgin forest are of this species. It frequently invades old fields and sometimes when openings develop in woods it comes up in almost pure stands. No. 115.

**Lonicera prolifera* (Kirch.) Rehder Honeysuckle, Aug. 26, 1931. Growing in the vicinity of Donaldson's home site. No. 127.

L. prolifera Rehder. Honeysuckle, Sept. 4, 1931. Woods. No. 183.

Malus glaucescens Rehder. Crab Apple, Aug. 29, 1931. Dry woods south of Upper Twin Cave. This plant has some of the characters of *M. ioensis* Britton. No. 174.

Menispermum canadense L. Moonseed. No collection.

Morus rubra L. Red Mulberry, Aug. 24, 1931. Virgin forest. No. 91.

Nyssa sylvatica Marsh. Black Gum, Aug. 19, 1931. Frequent in woods and old fields. No. 35.

Ostrya virginiana (Mill.) Koch. Hop-hornbeam, Aug. 19, 1931. Very common in the lower arborescent stratum of woods. No. 42.

Parthenocissus quinquefolia (L.) Planch. Virginia Creeper. Common in woods.

†*Philadelphus inodorus* L. Mockorange, Aug. 26, 1931. Escaped in the vicinity of Wilson's monument. No. 125.

†*Pinus virginiana* Mill. Virginia Pine, Aug. 26, 1931. Planted at the Donaldson's home site but not escaped from there because of the density of the surrounding woods. However, plants are to be found in the fields east of the virgin forest and northward a half-mile which have undoubtedly escaped from a grove of pine on the Bundy place about one-fourth mile south of the Park on route 60. This grove has spread over several acres. No. 137.

Platanus occidentalis L. Sycamore, Aug. 25, 1931. Common along streams. No. 116.

Populus deltoides Marsh. Eastern Cottonwood. No collection. One good-sized specimen stands near the gate house.

P. grandidentata Michx. Largetooth Aspen, Aug. 19, 1931. Old fields and thickets on high ground. No. 26.

Prunus americana Marsh. Wild Plum, Sept. 5, 1931. Thicket north of the gate house and route 60. No. 197.

P. serotina Ehrh. Black Cherry, Aug. 26, 1931. Woods. Seedling survival in the virgin forest seems to be good. No. 130.

Ptelea trifoliata L. Hoptree, Aug. 29, 1931. Infrequent, in woods near edge of Daltons' Cave. No. 170.

Quercus alba L. White Oak, Aug. 19, 1931. Most frequent and important tree in the virgin forest. The largest specimen is along the trail running back of Hamer's Cemetery towards the village. No. 29.

Q. alba latiloba Sargent. White Oak, Aug. 27, 1931. Two large trees distinctly of this variety were found on a hill near the Clouse place. Although there were no fruit for comparison, there was no mistaking the difference of these trees, even from a distance, from the species with which they were intermingled. No. 162.

Q. coccinea Muench. Scarlet Oak, Aug. 26, 1931. No fruit was found, so the identification is not positive. No. 132.

Q. imbricaria Michx. Shingle Oak, Aug. 19, 1931. Good fruit on trees situated at the edge of woods. Common. No. 25.

Q. macrocarpa Michx. Bur Oak, Sept. 22, 1931. Some with fruit. Species infrequent in the Park. Nos. 80 and 274.

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* Means, planted.

† Means, escaped from plantings, propagating spontaneously.

Q. marilandica Muench. Blackjack Oak, Aug. 22, 1931. In an old field above Donaldson's Cave—a single small tree. This may have been a lobed and toothed specimen of *Q. imbricaria* instead of *Q. marilandica* since no others were found. No. 100.

Q. Muhlenbergii Engelm. Chinquapin Oak, Aug. 19, 1931. This oak is common on upland places in the Park. No. 24.

Quercus palustris Muench. Pin Oak, Aug. 26, 1931. Suitable habitat for this species is infrequent in the Park. A few fine trees are to be found along the railroad north of the village. No. 139.

Q. borealis maxima (Marsh.) Ashe. Red Oak, Aug. 27, 1931. Common in woods. One fine tree is located immediately south of the upper Twin Cave. No. 161.

Q. shumardii var. *schneckii* (Britton) Sargent. Schneck Oak, Sept. 5, 1931. This oak resembles *Q. rubra* in form, while the buds are similar to *Q. palustris,* but the acorns are much too large for the latter. No. 195.

Q. stellata Wang. Post Oak, Aug. 25, 1931. In dry woods above Donaldson's Cave. Infrequent. No. 110.

Q. velutina Lam. Black Oak, Sept. 22, 1931. Common in woods and exposed places. Typical specimen with very loose and recurved scales on the cup is to be found near the road between the Cave camp ground and the Custodian's residence. Nos. 131 and 275.

Rhamnus lanceolata Pursh. Buckthorn, Sept. 4, 1931. Several specimens on dry hillsides overlooking the village on the west. No. 184.

Rhus copallina L. Dwarf Sumach, Aug. 25, 1931. Very common in old fields. No. 117.

R. glabra L. Smooth Sumach, Sept. 4, 1931. Old fields. No. 185.

R. toxicodendron L. Poison Ivy, no collection. Very common.

Ribes cynosbati L. Gooseberry, not collected.

**Robinia hispida* L. Hispid Locust, Aug. 26, 1931. Planted in Hamer's Cemetery. No. 128.

Rosa carolina L. Pasture Rose, Aug. 25, 1931. Common in dry oak woods above Donaldson's Cave. No. 104.

R. setigera Michx. Prairie Rose, Sept. 4, 1931. In dry oak woods west of the village. Leaves only slightly hairy. No. 193.

Rubus allegheniensis Porter. Common Blackberry, Sept. 5, 1931. Common. No. 198.

R. flagellaris Willd. Dewberry, Sept. 4, 1931. Open woods and fields. Does not fit the description any too well, but it is definitely of prostrate habitat. No. 194.

R. occidentalis L. Blackcap Raspberry, Sept. 4, 1931. Common in woods and fields. No. 192.

Salix nigra Marsh. Black Willow, Aug. 27, 1931. Common in moist sinkholes and along creeks. No. 153.

Sambucus canadensis L. Elderberry, Sept. 4, 1931. Especially common in low places. No. 186.

Sassafras variifolium (Salisb.) Ktze, Sassafras, Aug. 19, 1931. Most common of old field species. Occasionally in forests and of several inches diameter. No. 31.

Sp. glauca Walt. Glaucous Greenbriar, Aug. 25, 1931. Common in woods and fields. No. 119.

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* Means, planted.

S. hispida Muhl. Hispid Greenbriar, Aug. 25, 1931. In dry woods. No. 120.

S. rotundifolia L. Roundleaf Greenbriar, Aug. 19, 1931. Common in the virgin forest and in fields. No. 95.

Staphylea trifolia L. Bladdernut, Aug. 20, 1931. Dry woods. No. 67.

Symphoricarpos orbiculatus Moench. Indian Currant, Aug. 24, 1931. Very common in old fields and open woods. No. 20.

**Syringa vulgaris* L. Lilac, Aug. 26, 1931. Vicinity of the Donaldson's home site. No. 124.

Tilia glabra Vent. Basswood. No collection.

Ulmus alata Michx. Winged Elm, Sept. 5, 1931. Upland thicket north of route 60 and the gate house. The usual habitat southward is along streams although it seems to occupy dry hills in the northward extension of its range. This report is a new northward extension of range. No. 196.

U. americana L. American Elm, Sept. 4, 1931. Fine tree near the Tavern in the village. No. 187.

U. fulva Michx. Slippery Elm, Sept. 4, 1931. Common in woods. No. 188.

Vaccinium vacillans Kalm. Low Dryland Blueberry, Aug. 20, 1931. Oak woods near Donaldson's Cave and in the virgin forest. No. 53.

Viburnum acerifolium L. Mapleleaf Viburnum, Aug. 24, 1931. Common in the virgin forest and rich woods in general. No. 89.

V. pubescens deamii Rehder. Aug. 20, 1931. Frequent in rich woods in well-drained soil. No. 61.

V. pubescens indianense Rehder. Sept. 5, 1931. This variety can be found distinct from the preceding but intergrading plants can also be found. In woods west of Twin Caves. No. 200.

V. rufidulum Raf. Rusty Blackhaw, Aug. 25, 1931. Common in open woods especially on slopes and hilltops. This species is difficult to distinguish from *V. prunifolium* when the specimens have not reached the large size the former attains; in fact, the present decision rests on the fact that *V. rufidulum* is supposed to be the upland species of the hill country. No. 111.

†*Vinca minor L.* Periwinkle, Aug. 26, 1931. This escape, in the vicinity of Donaldson's Cave is a very serious menace to the native vegetation of the otherwise rich ravines. Although the evergreen Periwinkle makes a handsome appearance the native ferns and herbs should not be sacrificed to it. No. 126.

Vitis aestivalis Michx. Summer Grape, Aug. 25, 1931. Open upland woods and in the virgin forest. No. 121.

V. cordifolia Michx. Frost Grape, Aug. 25, 1931. Open fields and fences. No. 122.

V. vulpina L. Riverbank Grape, Aug. 24, 1931. Upland woods although its usual habitat is near streams. No. 94.

Xanthoxylum americanum Mill. Prickly Ash, Aug. 20, 1931. On dry hillsides with Celtis pumila, Rhamnus, etc. The writer has seen it in similar places in Orange and Scott counties, but northward it is in moist situations, as at Wolf Lake in Lake County. No. 60.

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* Means, planted.

† Means, escaped from plantings, propagating spontaneously.

STUDIES ON VIRGIN HARDWOOD FOREST: I—DENSITY AND FREQUENCY OF THE WOODY PLANTS OF DONALDSON'S WOODS, LAWRENCE COUNTY, INDIANA

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I. Introduction. Primeval, or "virgin" forests, timbered areas which have never been lumbered or grazed, are rapidly becoming exceedingly rare and of small area in the central hardwoods region. Exact statistical knowledge of the condition of such relics of the widespread forest known to the Indian and the early pioneers is not at hand. The early botanists had the description of new species and matters of distribution to occupy their attention. The overworked foresters, coming into the field later, were largely pressed by economic problems arising from the vast tracts of second-growth hardwood, overgrazed woodlots, abandoned agricultural land and erosion. The magnificent "interminable" forests which played such a commonplace rôle in the lives of our forefathers have practically become extinct, to the wonder and surprise of a later generation gradually becoming "outdoor" conscious, largely through the activities of such organizations as the Indiana Department of Conservation. The recognition of the immediate necessity for detailed study of the few remaining undisturbed forest tracts is spreading. It is to be hoped that the next few years will see the necessary expenditure of time and money by several workers and organizations to enable the satisfactory building up of a botanical picture of the forests our forefathers found necessary to destroy for the advance of civilization.

American students of plant communities have never considered it feasible to undertake as intensive studies as have the European ecologists and plant geographers. Plant sociological concepts as expressed by Braun-Blanquet and Pavillard (2) in their "Vocabulaire de Sociologie Végetále" and Braun-Blanquet (1) in the text "Pflanzensoziologie" are even yet somewhat strange to most, and largely dismissed with some such remark as, "Our flora (American) is so much richer and our territories larger! We could never afford the time to do such work!" The last few years, however, have seen a start in this type of botanical investigation by foresters, for example, Lutz (12, 13), grazing investigators as Hanson (8, 9), Sampson (18), McGinnies (14), and other ecologists as Gleason (6, 7), Kenoyer (10, 11), Nichols (15), Romell (17), and others. In another paper the writer, Cain (4), has presented a general discussion of Braun-Blanquet's concepts with a form for a table which will permit the maximum condensation of data. The headings for this table are presented here to show, both the fragmentary nature of the present paper and the possibilities which lie ahead in the plan for a complete description of virgin hardwood communities. The present paper presents data on density, dominance or coverage, here in the aspect of *basal area,* and frequency, i. e., the quantitative analytical aspects of the organization of a community. (Table I; 1 a, b, c).

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[1] It is the author's pleasure to thank the Indiana Department of Conservation for support afforded by that organization through the interest of Mr. Paul Brown and Mr. Edward Lacey. Mr. Dwight Billings of Butler University and especially Mr. Stanley Brooks of Indiana University are gladly recognized for assistance in field work, most of which could not have been accomplished by one worker.

It is hoped that, when a bulk of data on virgin forests are obtained, light will be thrown on several perplexing problems in ecology. For example, among the several authors who have attempted to map the distribution of the deciduous forest formation, its associations and sub-

TABLE I

Sociologic Résumé												Species List
I Organization									II Synecology		III	
A Analytic							B Syn-thetic		A		Genetic Sociology	
1 Quantitative			2 Qualitative						1 Physiog-nomy			
a	b	c	a	b	c	d	a	b	a	b	a	
Abundance*	Dominance	Frequence	Sociability	Vitality	Periodicity	Stratification	Presence†	Fidelity	Life-form	Leaf-size	Dynamic Behavoir	
1-5	1-5	1-5	1-5	1-3	1-4	1-4	1-5	1-5	1-α	1-α	1-5	Classes

* Abundance, expressed numerically, or as per cent, on a unit area basis is termed "density".

† Presence, expressed numerically or as per cent, on a unit area basis is termed "constance".

Table I. The form for a table which permits the most compact assembling of plant sociological data. No American plant community has been studied sufficiently intensively to permit the construction of such a table.

Note: The quantitative data (1) are derived from quadrats; the analytic data (A) from the study of some one community; the synthetic data (B) from the study of several different examples (stands) of the same community. There are other sociologic concepts but these are the only ones permitting assignment to definite classes of the species composing a community, and hence, tabular presentation.

climaxes, there is considerable discrepancy; Weaver and Clements (22), Schantz and Zon (19), Shelford (20), etc., yet no great attention has been paid to virgin areas, especially in regions of slow physiographic change. Again, as Deam and others have suggested for common weed trees, such as persimmon (Diospyros), sassafras, etc., a tremendous increase in abundance since the clearing of the forests and the later abandonment of wide acreage, especially in hill regions, it occurs to the writer that certain forest trees in partially cut climax woods may enjoy a greater abundance than in primeval conditions. This may be the case in some instances in the Beech-Maple climax, for the selective cutting of more valuable trees as white oak (Quercus alba), tulip (Liriodendron tulipfera), walnut (Juglans nigra), etc., may have left the way open for maple and beech to rapidly reach a stage where they alone are codominants, or form consociations. Also, in some work in a small tract of virgin forest at Turkey Run State Park, Esten (5) has found evidence which may be interpreted to show that maple is succeeding beech. There is a scattering of very large old monarch white oaks, a strong dominance of beech and a heavy reproduction of sugar maple (Acer saccharum). In DuBois County, about five miles north of Jasper, Indiana, there are several tracts of virgin timber. Figure 1 shows a beech woods with maple undergrowth from this region. So it is that detailed statistical studies will contribute much to the finer aspects of succession and the matter of consociations and of later serial stages in various hardwood regions.

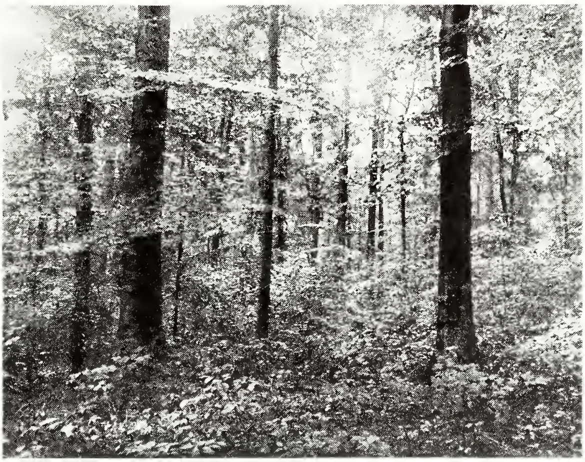
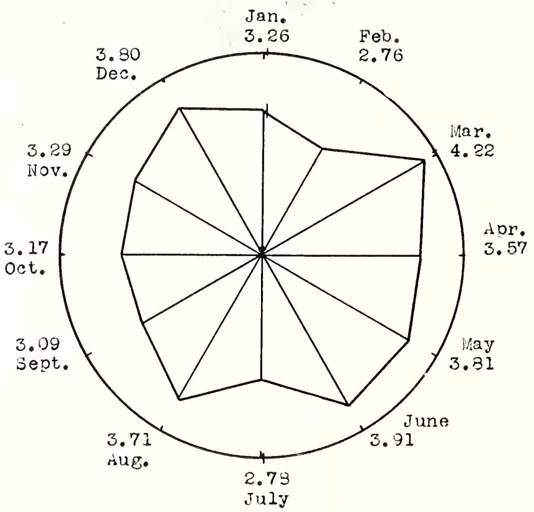


Fig. 1. Maple reproduction under beech consociation, near Jasper, DuBois County, Indiana.

II. The Area. Donaldson's Woods is one of the attractions at Spring Mill State Park, located about three miles southeast of Mitchell, Lawrence County, Indiana. The county is entirely within the unglaciated south-central portion of the state, usually referred to as the "Knobs."

Physiographically the area is in the regional unit known as the Mitchell plain, composed in the main of residual soils formed from the Mitchell limestone. In the soil survey of the county, Bushnell (3), the soils of Donaldson's Woods are referred to the Frederick silt loam. The region of the Park presents a most excellent example of the karst topography, with numerous sinkholes, sinkhole ponds and caves characteristic of underground drainage. The general elevation of the region is approximately 700 feet above sea level.

There is no weather station at the Park, but data from Bedford, about 14 miles to the north, and from Salem, about 25 miles to the southeast, are presented below. The mean annual temperature for Bedford is 55.1 F. and for Salem is 54.2 F., giving an average for the vicinity of Spring Mill State Park of 54.65 F. The mean annual precipitation at Bedford is 40.35 inches and at Salem is 42.67 inches, giving an average for the vicinity of Spring Mill State Park of 41.5 inches. These mean figures are taken from the annual weather report summarizing all available data up to and including 1925. The following figures present monthly precipitation averages. This type of diagram, figure 2, the writer believes was first introduced by Prof. Transeau at the Oxford meeting of the Ohio Academy, 1931.



Mean annual precipitation, 41.5 inches, Spring Mill

Fig. 2. Precipitation "rose" for the vicinity of Spring Mill State Park, constructed on the basis of monthly means.

III. The Vegetation. A. Methods. The shape and size of the tract to be studied was determined by running a line around the boundary with the aid of a steel tape and a U. S. Forest Service compass mounted on a Jacob's staff. From this outline map the location of the quadrats was determined to give maximum dispersal of twenty-five sets of quadrats well within the limits of the woods. Figure 3. The permanent quadrats consist of twenty-five plots, each 10 x 10 meters, for the study of all woody plants of one inch or more d. b. h. (diameter breast high, i. e., 4.5 feet above the ground). In the northeast corner of each of these quadrats was staked off additional ones 4 x 4 meters for the study by height classes of smaller woody plants. A study of herbaceous plants has not yet been made but the plan is to study one meter quadrats in each of the corners of the larger plots, as indicated in figure 3.

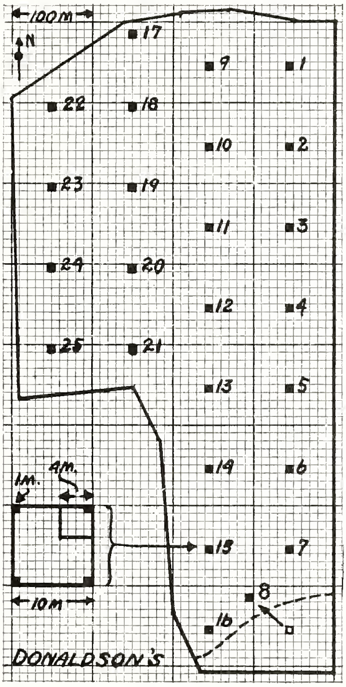
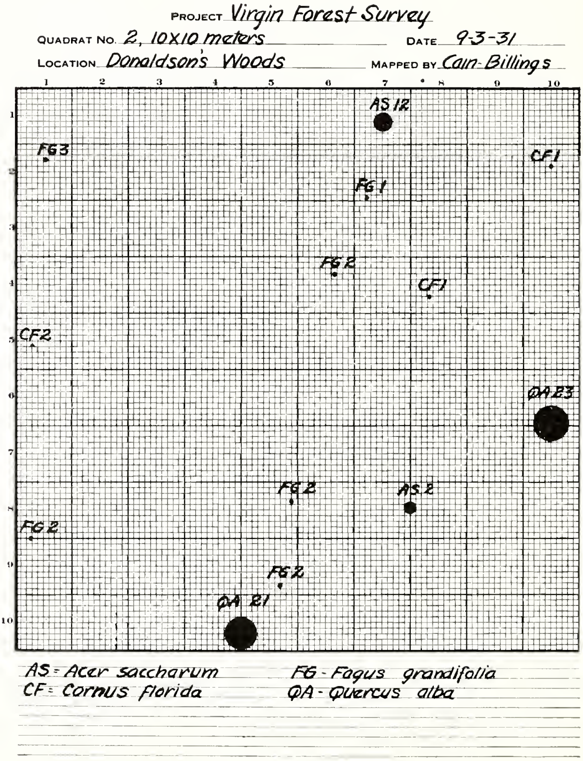


Fig. 3. Outline of Donaldson's Woods showing the position of 25 sets of permanent quadrats.

All quadrats were charted for permanent record. In the 100 meter quadrats the exact location and d. b. h. is given to scale for each stem over one inch. In the 16 meter quadrats the location and height by six inch classes is given, except for seedlings under six inches high, which are tabulated at the bottom of each quadrat sheet. For illustrations of the two types of quadrats see figures 4 and 5. From these data abundance, or rather *density*, which is abundance on a unit area basis, *frequence*, and basal area are computed. No effort was made to estimate *dominance* on a basis of coverage, by crown classes for each species. Collectively, however, the tree stratum would have class 5 coverage, 76-100 per cent. *Basal area,* which can be considered as one aspect of coverage, is computed from the results of the 25 10 x 10 m. quadrats.

Certain of the more important species are presented in a comparative manner by means of *phytographs,* a type of diagram devised by Lutz (12). The four axes of the phytographs are percentage expressions of (1) abundance of stems 10 inches d. b. h. or over, (2) frequency of stems 10 inches or over, (3) size classes in which the species is found (see Table V), and (4) basal area.



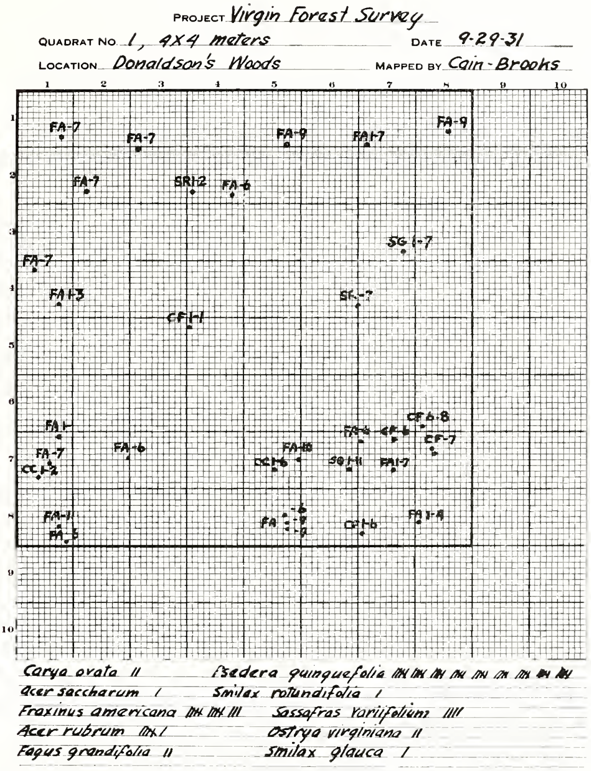
Project Virgin Forest Survey
Quadrat No. 2, 10x10 meters Date 9-3-31
Location Donaldson's Woods Mapped by Cain-Billings

Fig. 4. Sample quadrat sheet in which position and diameters of trees are indicated.

The field work was always done by two men. Exact compass lines were maintained for control, linear measurements and heights were made by metric steel tapes, while diameters were determined by calipers except for stems over 36 inches d. b. h. One man measured and the other recorded or charted as the case required.

B. Results. The results of this statistical study are considered under three headings, density, basal area, and frequency. Table II shows the symbols used in charting the 45 species of woody plants encountered in the survey. There may be a few other species which were unobserved. At the present, however, only *Campsis radicans* and *Celtis pumila* are to be added to the list.

Considering Table III which presents the density of all species encountered in the 25 quadrats, which were 10 x 10 meters in size, by inch classes, we find a total of 309 stems in 2,500 sq. m. area. This survey is approximately 1 per cent of the tract of 61 acres. The one, two and three inch diameter classes contain about 70 per cent of the total number of stems. The following species have stems 10 inches d. b. h. or over: *Acer saccharum, Carya glabra, Carya laciniosa, Fagus grandifolia, Fraxinus americana, Liriodendron tulipifera, Nyssa sylvatica Quercus alba, Quercus borealis* var. *maxima, Quercus velutina*. The most consistently represented species in the larger size classes is *Quercus alba*, with a maximum of 47 inches d. b. h. *Liriodendron tulipifera* is next with a maximum of 34 inches, although there were larger trees present in the tract outside the quadrats. Referring to Table IX, the species of greatest density are *Acer saccharum* with 43 stems, *Fagus grandifolia* with 36 stems, *Fraxinus americana* with 36 stems and *Quercus alba* with 26



PROJECT Virgin Forest Survey

QUADRAT NO. 1, 4X4 meters DATE 9-29-31

LOCATION Donaldson's Woods MAPPED BY Cain-Brooks

Carya ovata II

Acer saccharum I

Fraxinus americana 𝍸 𝍸 III

Acer rubrum 𝍸 I

Fagus grandifolia II

Psedera quinquefolia 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸 𝍸

Smilax rotundifolia I

Sassafras variifolium IIII

Ostrya virginiana II

Smilax glauca I

Fig. 5. Sample quadrat sheet in which position and height of woody plants are recorded from permanent quadrat.

stems. Among the small trees, *Cornus florida* is the only one of the six species of any abundance, with 98 stems.

TABLE II

Symbols used on quadrat maps for species of Donaldson's Woods

AR —Acer rubrum
AS —Acer saccharum
AC —Amelanchier canadensis
AT —Asimina triloba
BA —Benzoin aestivale
CaC —Carpinus caroliniana
CCd —Carya cordiformis
CG —Carya glabra
CL —Carya laciniosa
CO —Carya ovata
CS —Celastrus scandens
CLO —Celtis occidentalis
CC —Cercis canadensis
CF —Cornus florida
COb —Cornus obliqua
CA —Corylus americana
CR ? —Crataegus sp ?
EV —Evonymus atropurpureus
FG —Fagus grandifolia
FA —Fraxinus americana
FL —Fraxinus lanceolata
JN —Juglans nigra
LT —Liriodendron tulipifera
MC —Menispermum canadense
MR —Morus rubra
NS —Nyssa sylvatica
OV —Ostrya virginiana
PS —Prunus serotina
PQ —Parthanocissus quinquefolia
QA —Quercus alba
QI —Quercus imbricaria
QM —Quercus Muhlenbergii
QR —Quercus borealis var. maxima
QV —Quercus velutina
RR —Rhus radicans
SV —Sassafras officinale
SG —Smilax glauca
SR —Smilax rotundifolia
SO —Symphoricarpus orbiculatus
UF —Ulmus fulva
VV —Vaccinium vacillans
ViA —Viburnum acerifolium
VP —Viburnum prunifolium
VPD—Viburnum pubescens deamii
VA —Vitis aestivalis

TABLE III

Density of species by inch diameter classes from 25 quadrats, 10 x 10 meters: Donaldson's Woods

In. DBH	AR	AS	CG	CL	CO	CC	CF	FG	FA	LT	MR	NS	OV	QA	QR	QV	SV	VP	VA	Total
1	5	17	5	1	4	1	38	6	21	....	2	1	3	1	1	....	....	1	....	106
2	1	8	3	1	4	2	34	9	10	....	1	2	1	1	....	....	1	....	1	78
3	3	12	....	....	3	....	19	5	4	....	1	1	2	....	....	....	....	....	....	50
4	1	1	....	....	2	....	7	1	....	....	....	....	1	1	....	....	....	....	....	14
5	3	1	1	....	....	....	....	2	....	....	....	....	....	1	....	....	....	....	....	8
6	2	1	....	....	2	....	....	2	....	....	1	....	....	2	....	....	....	....	....	10
7	....	....	....	....	1	....	....	1	....	....	....	....	....	....	....	....	....	....	....	2
8	1	1	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	2
9	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
10	....	1	....	....	....	....	....	....	....	....	....	1	....	1	....	....	....	....	....	3
11	....	....	....	....	....	....	....	1	....	....	....	....	....	....	1	....	....	....	....	2
12	....	1	....	1	....	....	....	....	1	....	....	....	....	1	....	....	....	....	....	4
13	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	1
15	....	....	....	....	....	....	....	....	....	1	....	1	....	2	....	....	....	....	....	4
17	....	....	2	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	3
19	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
21	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
22	....	....	....	....	....	....	....	....	....	....	....	....	....	3	....	....	....	....	....	3
23	....	....	....	....	....	....	....	....	....	....	....	....	....	2	1	....	....	....	....	3
24	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
25	....	....	....	....	....	....	....	....	....	....	....	....	....	2	....	....	....	....	....	2
26	....	....	1	....	....	....	....	1	....	....	....	....	....	....	....	....	....	....	....	2
27	....	....	....	....	....	....	....	....	....	1	....	....	....	1	....	....	....	....	....	2
28	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	1
34	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	....	....	....	....	1
42	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
47	....	....	....	....	....	....	....	....	....	....	....	....	....	1	....	....	....	....	....	1
																				309

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[1] The scientific names used in this paper follow Deam's publications on trees and shrubs: Deam, C. C. "Trees of Indiana," Indiana Department of Conservation, 1932. Deam, C. C. "Shrubs of Indiana," Indiana Department of Conservation, 1924.

Table IV presents the density of all species encountered in 25 quadrats, each 4 x 4 meters, by six inch height classes. These include all plants under one inch d. b. h. of a woody nature. Any over 9.5 feet high, yet less than one inch in diameter are put in the last column. The species well represented throughout the height classes are: (AS) *Acer saccharum,* (CG) *Carya glabra,* (CF) *Cornus florida,* (FA) *Fraxinus americana,* (NS) *Nyssa sylvatica,* (UF) *Ulmus fulva.* In the smallest height class (AR) *Acer rubrum* shows especially heavy reproduction. Beech, (FG) *Fagus grandifolia* is conspicuously low in these small sizes although it holds up well in the larger size classes.

TABLE IV

Density of species by height classes (under 1 inch d. b. h.) derived from 25 quadrats 4 x 4 meters: Donaldson's Woods

Height by Feet

Symb.	.5—	.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0	9.5	plus
AR	106	17	5	2				1											1		1
AS	19	6	3	5	1		1		2	1	1		1		1		2		1		
AC	2																				
AT	6	1	4	2	1		1	1			1					2			1		
BA	32	6	18	1	1	2	1	1	4	1											
CaC	64	13	4	1	1		1	1	2	1											
CCd	4	2	1				2		1				1								
CG	43	15	6	1	8	2	3	2	2	1	1				3						1
CL			2	1		1	1														
CO	3						1														
CS	11	1	1																		
ClO	1																				
CC	27	2	4	2	1				1												2
CF	47	40	21	7	7	2	1		1	1	4			1	1	2	1				
COb	1																				
CA	3		3	5	1	1															
Cr?	2	1						1													
EA	1																				
FG	2	5										2									
FA	93	57	34	12	8	8	6	6	2		4	1	1	1	2	2	1	1	2	1	2
LT	10		1																		
MC	1	1		1																	
MR	5	2	2		2	1	1					1	1		1						
NS	2	1	1	2	2	1								1					1	1	
OV	19	2	1		1					1											
PS	20	3	5	2																	
PQ	1,432	2																			
QA	47	5																			
QR	2	3																			
RR	46	2	1																		
SV	48	3	3																		
SG	15	3	1	1																	
SR	83	6	3	1	1				1				1	1							
SO			2		1																
UF	57	22	7	2			1	1			2						1			1	
VV	9	10	1																		
ViA	21	8	8	4		1															
VP	2	2	2	1		1															
VPD	2		1																		
VA	13	6	5	2	4						1										

Computing on a common basis of 2,500 sq. m. area the following interesting contrast in density of size classes is found:

Woody plants under 1 in. d. b. h.	7,100
Woody plants from 1 to 9 in. d. b. h.	309
Woody plants 10 in. d. b. h. or over	38

TABLE V

Density of 11 species illustrated in the phytographs by five size classes (Based on 25 quadrats, 10 x 10 meters)

Species	up to 1 ft. high	1.5-12 ft. high	1-3 in. D. B. H.	4-9 in. D. B. H.	10 in. and over
Quercus alba	325	....	2	5	19
Quercus borealis var. maxima	31	....	1	....	3
Liriodendron tulipifera	69	....	....	....	3
Fagus grandifolia	44	12	20	6	2
Nyssa sylvatica	25	50	4	....	3
Acer rubrum	800	31	9	7	....
Carya cordiformis	44	25	....	....	....
Carya glabra	400	150	8	1	3
Fraxinus americana	1,150	319	35	....	1
Acer saccharum	175	100	37	4	2
Cornus florida	675	194	91	7	....

The basic figures for the sizes under 1 inch D.B.H. were taken from the 4 x 4 quadrats and multiplied by the figure necessary to make them equal to the density for 10 x 10 m. quadrats.

TABLE VI

Woody plants of Donaldson's Woods according to frequency derived from species 1 inch d. b. h. or over from 25 quadrats 10 x 10 meters each.

Class E, 1 species of 81-100% frequency—	
CF—Cornus florida	92%
Class D, 2 species of 61-80% frequency—	
QA—Quercus alba	72%
AS—Acer saccharum	68%
Class C, 3 species of 41-60% frequency—	
FG—Fagus grandifolia	48%
FA—Fraxinus americana	48%
CO—Carya ovata	44%
Class B, 2 species of 21-40% frequency—	
AR—Acer rubrum	40%
CG—Carya glabra	24%
Class A, 11 species of 1-20% frequency—	
NS—Nyssa sylvatica	20%
LT—Liriodendron tulipifera	12%
QR—Quercus borealis var. maxima	12%
OV—Ostyra virginiana	12%
CL—Carya laciniosa	8%
MR—Morus rubra	8%
CC—Cercis canadensis	4%
QV—Quercus velutina	4%
SO—Sassafras officinale	4%
VP—Virburnum prunifolium	4%
VA—Vitis aestivalis	4%

TABLE VII

Woody plants of Donaldson's Woods according to frequency derived from species less than 1 inch d. b. h. from 25 quadrats 4 x 4 meters.

Class E, 4 species of 81-100% frequency—

FA—Fraxinus americana	96%
CG—Carya glabra	84%
CF—Cornus florida	88%
PQ—Parthenocissus quinquefolia	84%

Class D, 5 species of 61-80% frequency—

UF—Ulmus fulva	80%
AR—Acer rubrum	64%
QA—Quercus alba	64%
SR—Smilax rotundifolia	80%
SO—Sassafras officinale	68%

Class C, 6 species of 41-60% frequency—

AS—Acer saccharum	56%
PS—Prunus serotina	48%
CC—Cercis canadensis	56%
VA—Vitis aestivalis	48%
RR—Rhus radicans	44%
ViA—Viburnum aerifolium	44%

Class B, 8 species of 2-40% frequency—

NS—Nyssa sylvatica	36%
LT—Liriodendron tulipifera	24%
CCd—Carya cordiformis	24%
CaC—Carpinus caroliniana	36%
BA—Benzoin aestivale	28%
MR—Morus rubra	28%
SG—Smilax glauca	28%
OV—Ostrya virginiana	24%

Class A, 17 species of 1-20% frequency—

FG—Fagus grandifolia	20%
CO—Carya ovata	12%
QR—Quercus borealis var. maxima	12%
CL—Carya laciniosa	8%
ClO—Celtis occidentalis	4%
CS—Celastrus scandens	20%
VP—Viburnum prunifolium	20%
CA—Corylus americana	16%
Cr?—Crataegus sp?	12%
SO—Symphoricarpus orbiculatus	8%
VPD—Viburnum pubescens var. deamii	8%
AT—Asimina triloba	4%
COb—Cornus obliqua	4%
EA—Evonymus atropurpureus	4%
AC—Amelanchier canadensis	4%
MC—Menispermum canadensis	4%
VV—Vaccinium vacillans	4%

On a basis of the 1 per cent survey there are 521 trees per acre one inch D. B. H. or over, while of the sizes less than that there are approximately 23,000 stems. The latter number is greatly increased by the abundance of (PG) *Parthenocissus quinquefolia*, the virginia creeper; (RR) *Rhus radicans*, the poison ivy, etc.

Table V gives the density of the species illustrated by the phytographs at the close of this section, on a basis of five size classes.

The frequence of species is usually expressed by five classes, or directly in percentages. Frequence refers to the number of quadrats in which a species occurs and is expressed in terms of per cent of the total number of quadrats examined in the particular study. For example, if a certain species is found in 10 out of 100 quadrats examined, totally disregarding the abundance of the species, it would have 10 per cent frequence. Again, if it was found in 23 out of 25 quadrats the frequency would be 92 per cent. It has been found more convenient and easier to comprehend if the frequency percentages from all the species in a community analyzed are thrown into five classes. Frequency class 1 contains all species from 1 to 20 per cent frequent, and similarly, F.2 contains those from 21 to 40 per cent; F.3, 41 to 60 per cent; F.4, 61 to 80 per cent, and F.5, 81 to 100 per cent. These classes are sometimes referred to as A>B>C>D<E in which each succeeding class is smaller except the last, Class E being larger than D under normal conditions.

TABLE VIII

Comparison of frequency of species from 2 sets of quadrats: 25 quadrats, 10 x 10 meters; 25 quadrats, 4 x 4 meters

Species	Frequency Percent			Life Form
	10x10m. 1 in. D. B. H. or over	4x4m. under 1 in. D. B. H.	Difference	
Cornus florida	92%	88%	plus 4	small tree
Quercus alba	72	64	plus 8	tree
Acer saccharum	68	56	plus 12	tree
Fagus grandifolia	48	20	plus 28	tree
Fraxinus americana	48	96	minus 48	tree
Carya ovata	44	12	plus 32	tree
Acer rubrum	40	64	minus 24	tree
Carya glabra	24	84	minus 60	tree
Nyssa sylvatica	20	36	minus 16	tree
Liriodendron tulipifera	12	24	minus 12	tree
Quercus borealis var. maxima	12	12	0	tree
Ostrya virginiana	12	24	minus 12	small tree
Carya laciniosa	8	8	0	tree
Morus rubra	8	28	minus 20	small tree
Cercis canadensis	4	56	minus 52	small tree
Quercus velutina	4	0	plus 4	tree
Sassafras officinale	4	68	minus 64	small tree
Viburnum prunifolium	4	20	minus 16	small tree
Vitis aestivalis	4	48	minus 44	vine

Briefly then, this means that there are more species in a community which will be found to have low frequency. In Table VI, for example, there is only one species in Class E while there are 11 species in Class A. In this table the frequency is computed on a basis of the occurrence of a species in the 25 quadrats, each of 100 sq. m., considering only woody plants of 1 inch d. b. h. or more. Table VII is similar, but considers only woody plants of sizes under 1 inch d. b. h. from smaller quadrats, 25 of them, 4 x 4 meters. Table VIII presents the differences found from the two computations.

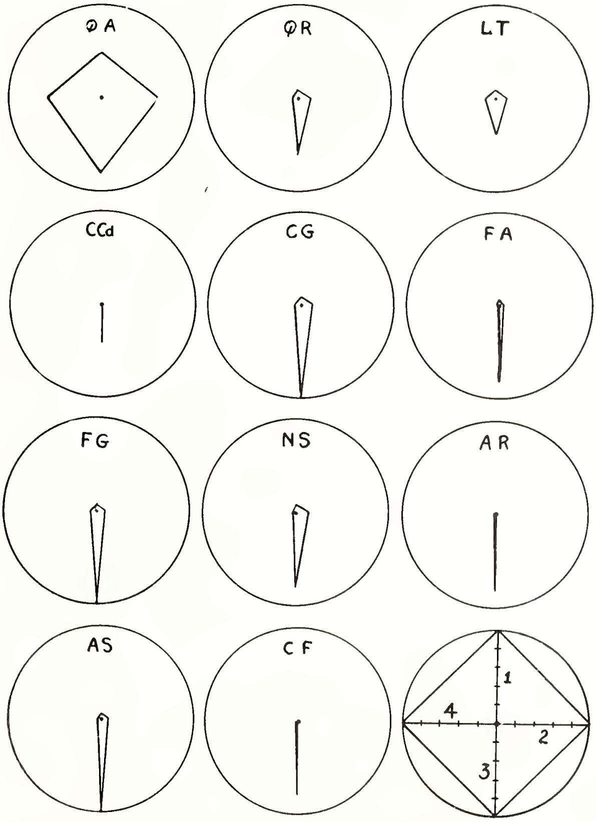

Fig. 6. Phytographs of the more important trees of Donaldson's Woods.

Basal area is the cross-sectional area of a tree or stand, in square feet measured at four and one-half feet above the ground, (d. b. h.) This is obtained from area of circles whose diameters equal those of the trees measured. There is never any attempt to account for the fact that the tree is seldom a circle in cross-section, except to average diameters at right angles when the tree is especially a-symmetrical. Table IX presents the results of the basal area computations from the one per cent survey (10 x 10 m. quadrats) together with similar data from a 10 per cent survey. For the latter, strips connecting the quadrats in a

TABLE IX

Basal Area Study of Donaldson's Woods

SPECIES	1% Survey				10% Survey			
	25 quads 10 x 10 m. .61 acres B.A., sq. ft.	No. stems	Average B. A. per stem	B. A. per acre sq. ft.	10 m. strips	No. stems	Average B. A. per stem	B. A. per acre sq. ft.
Quercus alba	64.904	**26**	**2.500**	**106.40**	380.527	**203**	1.878	**62.38**
Quercus borealis var. maxima	4 475	4	1.119	7.33	69.186	48	1.441	**11.34**
Liriodendron tulipifera	11.510	3	**3 837**	**18.87**	50.905	23	**2.213**	8.34
Fagus grandifolia	5.890	**36**	.164	**9.66**	26.838	**209**	.128	4.40
Nyssa sylvatica	3.453	7	.493	5.66	18.315	53	.346	3.00
Acer rubrum	1.430	16	.089	2.34	17.635	**104**	.170	2.89
Carya cordiformis					16.856	11	1.532	2.76
Carya glabra	7.077	12	.590	**11.60**	16.551	88	.188	2.71
Fraxinus americana	1 360	**36**	.038	2.23	15.821	**187**	.084	2.60
Juglans nigra					14 110	4	**3.527**	2.31
Acer saccharum	2.947	**43**	.068	4 83	12.602	**235**	.054	2.07
Carya ovata	1.088	16	.068	1 78	10.389	58	.179	1.70
Carya laciniosa	812	3	.271	1 33	thrown with Carya ovata			
Quercus velutina	4 280	1	4 280	7 01	thrown with Quercus borealis var. maxima			
Quercus imbricaria					3.546	2	1.773	.58
Quercus muhlenbergii					2.890	1	2.890	.48
Ulmus fulva					2 014	22	.091	.33
Celtis occidentalis					.228	3	.076	.04
Prunus serotina					.196	1	.196	.03
Cornus florida	2 478	**98**	025	**4 06**	18 438	**713**	.025	**3.02**
Sassafras officinale	.022	1	022	.04	2.759	25	.110	.45
Ostrya virginiana	.222	7	.032	.36	2.758	107	.026	.45
Carpinus caroliniana					1 148	42	.027	.19
Morus rubra	.277	5	055	.45	.648	17	.037	.10
Cercis canadensis	049	3	016	.08	.189	10	.019	.03
Asimina triloba					.020	4	.005	.003
Amelanchier canadensis					.015	3	.005	.002
Viburnum prunifolium	.005	1	005	.01	.010	2	.005	.001
26 species		318 **521 per acre**		184.14 sq. ft.		2,175 **357 per acre**		112.206 sq. ft.

north-south direction were examined. These strips were 10 m. wide (approximately one-half chain) and were 90 m. between strips. The discrepancy between the two talleys when expressed on an acre basis is difficult to account for. Certainly the ten per cent cruise is the most reliable as a measure of the stand. It may have so happened that especially large trees fell in the 25 quadrats. Both surveys reveal the importance of the following species: *Quercus alba, Liriodendron tulipifera, Fagus grandifolia* and *Acer saccharum*. *Cornus florida* is conspicuously the most important of the small trees.

In Table X is found the data used for the construction of the phytographs. See Figure 6. *Quercus alba* is shown to be especially important, rating high in respect to all four of the criteria, abundance, frequency, distribution through size classes and basal area. For the method of computation of these data see Table X.

C. **Discussion.** In 1927 *Tillotson* (21) said that the Central Hardwood Region included about 40,000,000 acres of woodland in Ohio, Indiana, Illinois, Iowa and Missouri, the southern portions of Michigan, Wisconsin and Minnesota, the eastern edge of Nebraska and Kansas, the northeastern corner of Oklahoma, northern Arkansas and western half of Kentucky and Tennessee. About "three-fourths of the timber-producing acreage is in the form of farm wood lots, generally 10 to 40 acres in extent. Continual cutting of the best species and individuals, forest fires, and heavy pasturing have rendered these stands badly dilapidated and decadent . . . . so that the greater portion of the timber is on a slow but seemingly sure march to extinction. . . . . unless present practices are materially altered. A few virgin stands are still in existence, generally individual pieces of timberland held off the market for personal reasons by the owners, or else stands relatively inaccessible." The Central Hardwood Forest Experiment Station men found it difficult to locate some thirty-odd tracts of virgin timber for scientific studies of soil conditions, etc. *Pegg* and *Thomas* (16), writing in 1909 concerning the advisability of scientifically controlled wood lots for Indiana, remark on the rapid depletion of the timber. "Official records, which begin in 1870, show an acreage of 7,189,334 acres in timbered lands in Indiana. In 1880 only 4,335,000 acres were left. By 1890 over 2,500,000 acres more were cleared, of which 75,000 acres became waste land. Then Indiana ranked fifth with the states of the Union in the total output of lumber. In 1907 she ranked twenty-seventh."

Wherever one reads about forestry conditions one finds essentially the same story, with the exception, however, of an upward look in some states, especially those with classified land taxation. There are two common points of view concerning forest land. The one which held sway too long and completely was that trees are to be cut for their immediate profit, regardless of future consequences, the result being our

TABLE X

Data for Construction of Phytographs: 11 Species

Species	Radius 1: Abundance	Radius 2: Frequency	Radius 3: No. of Size Classes	Radius 4: Basal Area
Quercus alba	50%	56%	4	58%
Quercus borealis var. maxima	8	12	3	4
Liriodendron tulipifera	8	12	2	10
Fagus grandifolia	5	8	5	5
Nyssa sylvatica	8	12	4	3
Acer rubrum	....	....	4	1
Carya cordiformis	....	....	2	....
Carya glabra	8	12	5	6
Fraxinus americana	4	4	4	1
Acer saccharum	5	8	5	3
Cornus florida	....	....	4	2

1—*Abundance:* each species figured as a per cent of the total number of stems 10 inches D.B.H. or over.

2—*Frequency:* each species figured on a basis of the 25 quadrats, 10 x 10 meters, i.e. per cent of quadrats containing stems 10 inches D.B.H. or over.

3—*Size Classes:* each species indicated according to the number of the five size classes in which it is found. See table V.

4—*Basal Area:* each species expressed as a per cent of the total basal area of all species computed on a basis of sq.ft. per acre.

present conditions; the other too sentimental and impractical, that not a tree should be cut. We have people with the latter point of view to thank, however, for the preservation of the few remaining tracts of virgin hardwood in the Central West. Between waste and exploitation, and sentiment, is the rational viewpoint of the forester, considering the forests to be a long-rotation crop, to be utilized, yet perpetuated. One cannot help but wish, at this late date, that seventy-five or a hundred years ago some one had thought of establishing state parks, so that larger areas of primeval forest would have been preserved for recreation, inspiration and as museums and scientific laboratories. The small areas which remain at Turkey Run, Spring Mill, and under private ownership are none the less admirable. It behooves the present generation of botanists and zoologists to study these tracts intensively before they, too, diminish or are modified.

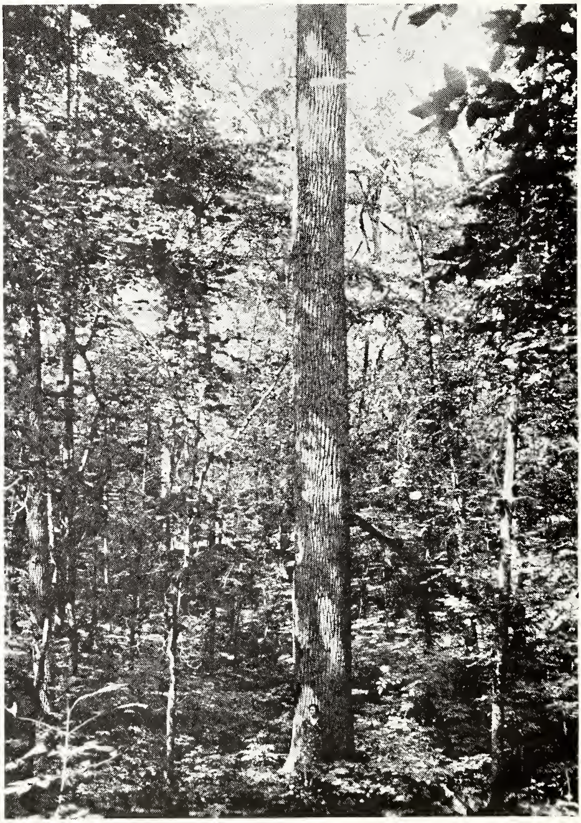

Fig. 7. One of several handsome specimens of Yellow Poplar, *Liriodendron tulipifera*, found in Donaldson's Woods.

Virgin forests are uneven-aged, over-ripe old monarchs overtopping and choking off the reproduction. When the pioneers first came it was not uncommon to find yellow poplar, oak and other species 150, 175 and almost 200 feet high with a girth of 25 feet. Today such a handsome tree as the poplar in Figure 7 is a monument, and trees five to six feet in diameter worthy of a long pilgrimage to see. Everywhere under these large trees the smaller trees, shrubs and herbaceous plants struggle for light while their root systems undergo severe competition for moisture. A spongy mass of forest litter makes a floor that holds rainfall and yet makes difficult the germination of certain lighter seeds. Very striking, however, is the abundant reproduction in the smaller size classes; seedlings up to a foot or so in height and saplings one to three inches or so in diameter. Everywhere they are waiting for one of the old trees to die and make an opening in the dense canopy into which they can grow in the severe struggle for existence. One needs only to examine the tables in this paper for examples of this situation. Yet to use such data for interpretation of matters of succession is extremely hazardous, for the elements of chance play a large part in what species are present at the right time and place to take advantage of opportunities for survival. For example, on a basis of a single study, such as this one of Donaldson's Woods, it would be unwise to say that white oak and yellow poplar; at present of high dominance, will be replaced by sugar maple, white ash and beech as the dominants die off, simply because of their greater density in the smaller size classes. Something of survival ability in the intermediate ages must be known. Then there is the matter of good and bad seed years for different species. The large number of seedlings of *Acer rubrum, Carya glabra, Fraxinus americana,* and *Ulmus fulva* may only be a temporary aspect. These are the matters which make the establishment of permanent quadrats important and the study of several comparable stands imperative if any adequate knowledge of virgin forest conditions is to be attained.

IV. Summary and Conclusions. Permanent quadrats have been established in a virgin forest tract known as Donaldson's Woods, located at Spring Mill State Park, where they will be protected and available for future study. Detailed investigation has been made of density, frequency and basal area of the woody plants encountered in the survey, which data, however, are only a fragment of the complete sociological study of the vegetation which it is proposed to complete as rapidly as time permits. Similar studies on other virgin forest tracts are to be undertaken so that data will be comparable and certain synthetic concepts built up. It is hoped that ample facilities will be provided for the larger task.

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PLANTS NEW OR RARE TO INDIANA, XVII

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Specimens of all of the species reported in this paper are in the Deam Herbarium and duplicates of all except Potentilla have been sent to other herbaria.

Tripsacum dactyloides L. Spencer County, October 10, 1931, No. 51,560. Common for a quarter of a mile along a ditch in a "flat" about five miles east of Lincoln City. It grew here mostly to a height of 4-6 feet. Most of the specimens were past the flowering stage and the fruit had fallen.

Commelina hirtella Vahl. This is a species of low ground, mostly of the southwestern part of the state. I have specimens from Daviess, Dubois, Gibson, Greene, Jackson, Jennings, Knox, Perry, Posey, Spencer, Warrick, and Washington counties.

Froelichia campestris Small. Newton County, August 19, 1930. Along a sandy roadside about six miles south of Roselawn. Collected by Miss Madge McKee of Goodland, Indiana, who graciously permitted me to make this report.

Potentilla simplex var. *argyrisma* Fernald. Benton County, July 31, 1912, No. 11,853. Along the railroad near Barce.

Geranium Robertianum L. Noble County, July 25, 1931, No. 50,707. A small colony at the base of a white-black oak slope on the west side of the road in Section 31 about a mile south of Alcinda or three and a quarter miles southwest of Cromwell. St. Joseph County, July 22, 1930, No. 49,249. Common in a low woods about two miles east of Woodland. Here it was associated with white elm and soft maple. I collected it in the same woods in 1931. This species was reported for the dunes area by Peattie, but I have not seen his specimen.

Helianthus angustifolius L. Pike County, October 8, 1931, No. 51,516. Common in colonies over 2-3 acres of a moist pasture field on the farm of Robert Grubb, about 6.2 miles southwest of Petersburg. Cattle did not eat it.

Helenium tenuifolium Nutt. Warrick County, October 7, 1931, No. 51,497. This species covered about 25 per cent of a 4-acre, moist hog lot on the farm of Oscar Kiser, about four miles northwest of Yankeetown. The hogs did not molest it.

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PLANT RESPONSES TO SAWDUST

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Sprouting seeds in sawdust has been a common practice in botanical laboratories for many years. A failure to get good root development in *Vicia faba* L. in sawdust of unknown source initiated the following preliminary experiment: a number of seeds were planted in fresh sawdust from *Quercus alba* L. and *Fagus grandifolia* Ehrh. In Quercus the roots were brown and did not penetrate the sawdust more than two centimeters, while in the Fagus sawdust the roots were well developed, white and contained hairs. The above experiment indicates that root development may depend on the kind of sawdust used.

An experiment was performed with sawdust from thirty-two species of Indiana woody plants, in *Swietenia mahogoni* Jacq., *Tsuga heterophylla* (Raf.) Sarg., and *Pseudotsuga taxifolia* (Lam.) Britton. With the exception of the last three species, the sawdust was made from specimens between fifteen and twenty centimeters in diameter. The same saw was used in order to have the sawdust of the same texture. Eight of the following plants were grown in each kind of sawdust:

Zea mays L.
Helianthus annuus L.
Ipomoea purpurea Roth
Lycopersicum esculentum Mill
Cucurbita pepo L.
Pisum sativum L. (early Alaskan variety)
Triticum aestivum L.
Phaseolus multiflorus Willd.

All plants were grown in containers of the same size, in a greenhouse where the temperature was about 70° F. These plants, sixty-four in each kind of sawdust, were grown for three weeks from the time they emerged. The tops were measured in centimeters, the average for the sixty-four being shown in column one of the following table. The tap and lateral roots were measured in centimeters; the average for the sixty-four plants is shown in column two; column three shows the sum of the average stem and roots. It is evident from this table that for the sixty-four plants Aesculus sawdust gives four times the stem growth that *Quercus alba* gives, and over thirty times the root growth. Sawdust from Aesculus, Ostrya, Gleditsia and Cornus gave better results than did a sandy loam soil.

In the individual experiments, Phaseolus in Ulmus sawdust made the best root growth, with an average of 647 cm., followed by Zea in Aesculus, 504 cm., Pisum in Aesculus, 287 cm., Cucurbita in *Acer sac-*

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charum, 180 cm., Helianthus in Aesculus, 171 cm., Ipomea in Aesculus, 165 cm., Triticum in Morus, 145 cm., and Lycopersicum, in soil, 40 cm.

The peas produced excellent nodules in Aesculus. Root hair developmen was very poor in most kinds of sawdust, especially in Quercus. The scarlet runner bean, in six weeks, produced fruit when growing in Amelanchier sawdust.

The results which are reported may throw light on the great differences experienced by farmers of Ripley County, Indiana, who have used sawdust on cultivated land, especially so where mills cut only one variety of sawdust—one cutting oak, another beech or maple, sweet gum, elm or basswood, as the case might be.

	Average height of 64 plants, in cm.	Average root system of all plants in cm.	Average plant: sum of root and stem in cm.
Aesculus glabra Willd	26.6	257.8	284.4
Ostrya virginiana (Mill) K. Koch	29.6	159.4	189.0
Gleditsia tricanthos L.	26.3	162.1	188.4
Cornus florida L.	24.9	163.0	187.9
Soil—sandy loam	37.2	140.0	177.2
Liquidambar styraciflua L.	26.0	144.9	170.9
Pyrus malus L.	23.1	146.5	169.6
Morus rubra L.	25.6	139.8	165.4
Platanus occidentalis L.	28.3	136.4	164.7
Asimina triloba (L.) Dunal	18.9	140.1	159.0
Ulmus americana L.	27.5	123.8	151.3
Carpinus caroliniana Walt.	22.5	106.3	128.8
Tilia americana L.	25.6	103.0	128.6
Juglans nigra L.	20.1	91.8	111.9
Pinus strobus L.	21.2	90.7	111.9
Swietenia mahogoni Jacq	24.2	87.4	111.6
Acer saccharum L.	27.1	78.7	105.8
Vitis labrusca L.	20.6	83.7	104.3
Fraxinus americana L.	27.2	74.0	101.2
Betula lutea Michx.	22.1	73.4	95.5
Acer rubrum L.	23.1	70.1	93.2
Amelanchier canadensis (L.) Medic	33.3	56.1	89.4
Fagus grandifolia Ehrh.	18.3	68.0	86.3
Liriodendron tulipifera L.	22.5	63.5	86.0
Nyssa sylvatica Marsh.	26.1	57.7	83.8
Salix nigra Marsh.	25.8	54.3	80.1
Alnus incana (L.) Moench	24.5	54.3	78.8
Sassafras variifolium (Salisb.) Ktze.	23.7	51.2	74.9
Prunus serotina Ehrh.	23.4	50.6	74.0
Tsuga heterophylla (Raf.) Sarg.	18.0	50.9	64.9
Populus tremuloides Michx.	28.6	37.4	66.0
Carya ovata (Mill) K. Koch	27.0	36.9	63.9
Juniperus virginiana L.	17.9	37.3	55.2
Pseudotsuga taxifolia (Lam.) Britton.	13.8	41.1	54.9
Quercus velutina Lam.	15.3	25.2	40.5
Quercus alba L.	7.9	8.1	16.0

AN INEXPENSIVE RECORDING TRANSPIROMETER

RAYMOND E. GIRTON, Purdue University[1]

In the quantitative study or demonstration of transpiration, it is frequently desirable to have an apparatus available which will automatically and continuously record the amounts of water lost by transpiring plants. The instrument herein described has been designed to fill this need at a very small cost, or at no cost at all if access is had to a few simple materials. As constructed by the author, the apparatus was made entirely of articles found in and about the botanical laboratories at Purdue, including such objects as old curtain rollers, aluminum lids, several large needles, and a piece of photographic film. The result was an instrument which could be used conveniently for following the loss of water by evaporation from a potted plant or free water surface, or from both sources at the same time.

The apparatus under consideration is given the name "*transpirometer*," although this term does not seem to be used in text books of plant physiology or in the better known writings on transpiration. Instruments for measuring temperatures, however, we designate as thermometers, instruments for measuring barometric pressures as barometers, and apparatus for measuring respiration as respirometers. Therefore it appears logical to use the term "*transpirometer*" for an instrument which is constructed for measuring transpiration. The term "*transpirometer*" will accordingly be applied to the apparatus under consideration.

Description of the Apparatus. Figure 1 shows the transpirometer to consist of an arrangement of the following parts. A long extension spring (f) is attached to a bolt (e) bent in the form of a hook. This bolt passes through a wooden spool (b) which is firmly supported by the clamp (c) and ring stand (d). A thumb nut (a) permits a fine adjustment in height of the spring and consequently of the pot with plants (n). The lower end of the spring is fastened to a double aluminum strip (i) which is turned up at its lower end to form a hook through which the loop of wire (m) supporting the plants passes. The strip (i) is also provided with two small holes, thus serving as a pivot bearing for the needle pivot of the aluminum lever arm (g). The fulcrum seat (h) for the lever is also of aluminum and is screwed to a wooden block supported by the clamp (k) and ring stand (l). Both the fulcrum seat (h) and the double aluminum strip (i) are slotted so that the lever arm may be easily slipped into or out of position without disturbing the remainder of the apparatus.

The essential part of the transpirometer is the spring (f) which supports the experimental plants. Loss of water by transpiration ma-

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[1] The author is indebted to Professors G. E. Read and J. H. McKee for their careful reading and criticism of the manuscript.

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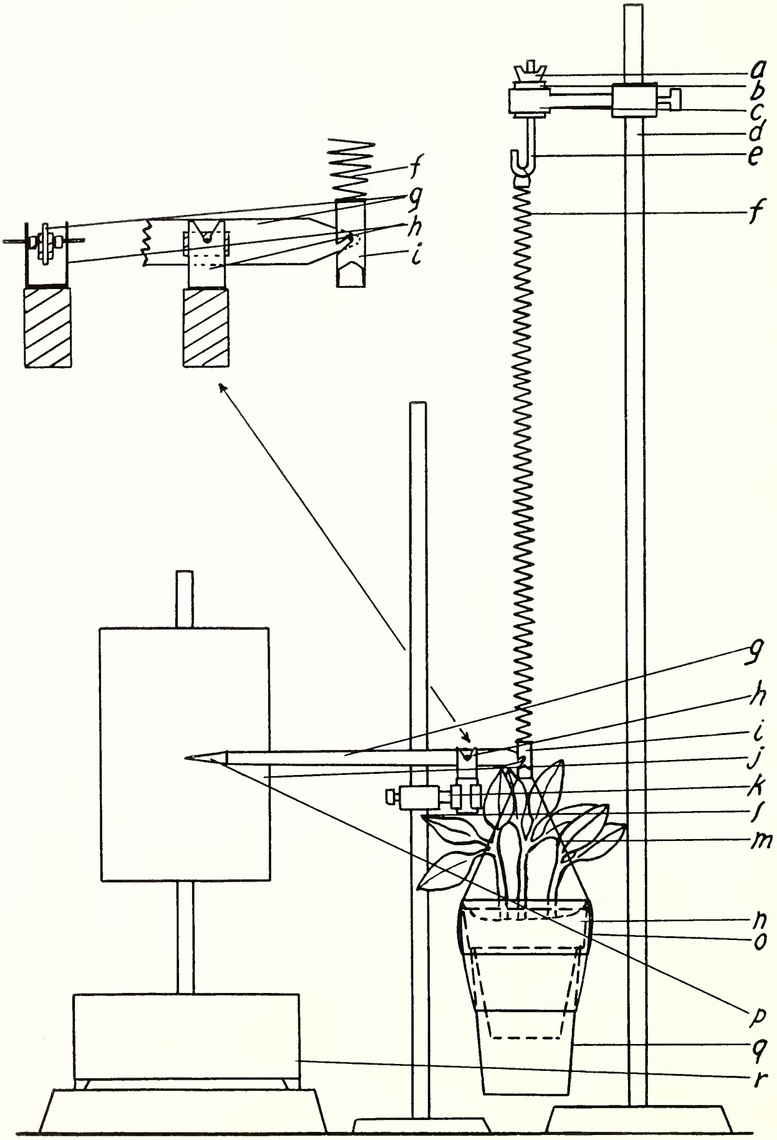

Fig. 1—Recording transpirometer. (a) thumb nut, (b) spool guide, (c) clamp, (d) ring stand, (e) hook bolt, (f) spring, (g) lever arm, (h) fulcrum seat, (i) pivot-bearing strip, (j) drum, (k) clamp, (l) ring stand, (m) supporting wire, (n) pot with plants, (o) rubber-strip seal, (p) stylus, (q) aluminum beaker, and (r) clinostat.

terially lessens the weight of the potted plant, thereby causing the spring to contract. The amount of contraction is magnified by the lever arm (g) and recorded graphically upon smoked paper attached to the slowly revolving drum (j). A very satisfactory spring for this purpose may be obtained from an old curtain roller. This spring easily supports a weight in excess of one kilogram and is sensitive to relatively small changes in weight.

In setting up the apparatus a four and one-half-inch pot of soil containing some rapidly transpiring plants is used. After a thorough irrigation, the soil is allowed to drain for a short time before the pot is placed in the aluminum beaker (q). A three-inch section of rubber inner tubing from an automobile tire is then fitted over the pot and beaker to prevent lateral water loss. This rubber strip extends slightly above the edge of the pot, so that the coating of warm wax mixture, which is next applied, effectively seals the soil and exposed inner pot surfaces from evaporation. The sealed plant is then attached to the hook at the lower end of the spring as indicated in the diagram. After the fulcrum seat (h) has been aligned with the pivot bearing (i), the lever arm may be slipped into place. The position of the lever is then easily adjusted up or down by means of the thumb nut (a). It is desirable to adjust the lever arm initially so that the part in contact with the revolving drum has an agle of 10-20 degrees above the horizontal. As weight is lost by the evaporation of water, the lever arm gradually falls past the horizontal axis to some position below, depending upon the total amount of water lost. Where the angle of the lever arm movement is not too great, vertical distances measured from a horizontal reference line may be taken as a direct measure of the water loss. If the weight of the potted plant is determined initially and at the completion of an experiment, the total water loss thus obtained divided by the total vertical distance through which the celluloid stylus (p) has moved, gives the number of grams transpired equivalent to one centimeter vertical distance on the drum. With the aid of this factor the amount of water lost can be determined for any time desired if the rate of drum rotation is known. The drum used by the author was revolved once in 12 hours by the clinostat (r).

When operating the transpirometer, certain precautions must be observed to insure satisfactory results. The celluloid stylus attached to the end of the lever arm should be kept pressed against the drum with a force sufficient to leave a clear mark, but not great enough to interfere with the movement of the lever. The spring (f) changes appreciably in length with changing temperature. Where a considerable range of air temperatures is encountered, a correction for this factor may be desirable. Exposure to strong sunlight also results in a considerable increase in the length of the spring due to heat absorption. For this reason it is advisable to shade the spring from direct sunlight when conducting experiments with changing light intensities. Finally it should be stated that while the apparatus can be operated in a light breeze from an electric fan, strong air currents are highly unsatisfactory.

Certain supplementary pieces of apparatus have proved useful in performing experiments with the transpirometer. They include a good laboratory balance for taking initial and final weights of the transpiring plant, a reliable thermometer for determining air temperatures, and a wet and dry bulb apparatus for making humidity determinations. Should it be desired to compute transpirational water loss per unit leaf surface area, blueprint paper and a planimeter will be necessary for measuring leaf areas. A recording thermometer may also be useful for providing correction data where large temperature fluctuations are encountered.

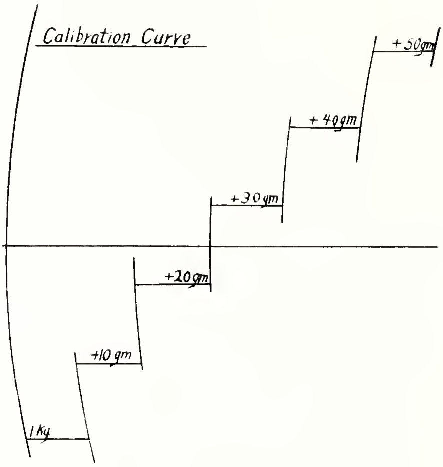

Fig. 2—Calibration-curve record obtained for a one kilogram load plus additional 10 gram increments.

Preliminary Tests. Several trial experiments were carried out in order to test the elasticity of the spring. In one case, a kilogram weight was suspended for a period of 20 hours. No appreciable increase in length was recorded in the revolving drum. This was true, however, only after a preliminary stretching had been effected by the same weight. For this reason it is considered desirable to expand the spring for several hours before setting up an experiment with an unstretched spring.

A test of a second type was made to determine the relation between

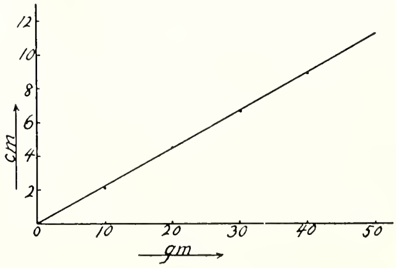

Fig. 3—Calibration curve based upon data obtained from the drum record shown in figure 2.

the length of the extended spring and the weight supported. The spring was first stretched with a one-kilogram weight. Further increases in length due to the addition of other weights were recorded over a range of 50 grams. The record obtained from this test is shown in Figure 2. These results when plotted demonstrate a linear relationship between weight and distance as indicated in Figure 3.

Transpiration Records. Several experiments were performed with transpiring plants under fairly uniform temperature conditions in order to observe the apparatus in actual use. These tests were conducted over different lengths of time and with varied environmental conditions.

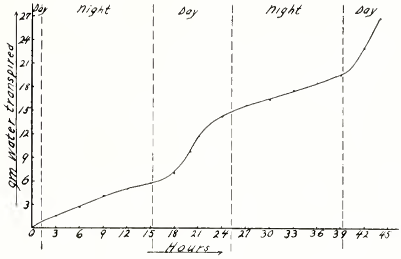

Fig. 4—Transpiration curve for potted bean plants under laboratory conditions. Transpiration values are expressed as actual amounts of water lost in grams.

The first of these experiments extended over a period of 44 hours and traced the course of transpiration of potted bean plants exposed to alternate darkness and to daylight of low intensity in the laboratory. The resulting curve plotted from values determined at three-hour intervals is shown in Figure 4. The increased rate of transpiration during daylight, in spite of dull and cloudy weather, is easily seen by the greater steepness of the parts of the curve corresponding to the daylight hours. A second transpirometer (results not shown) carrying a sealed control pot was operated for the same period and indicated only slight fluctuations from the horizontal reference line due to temperature changes and possibly a slight stretching of the spring.

A repetition of the preceding experiment was carried out for a shorter period (21 hours) in the greenhouse with similar results. In

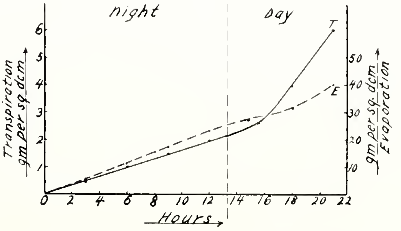

Fig. 5—Transpiration from potted bean plants under greenhouse conditions compared with evaporation from a free water surface. The water loss is expressed in each case as grams per square decimeter of exposed surface. T=transpiration curve. E=evaporation curve.

this experiment an aluminum beaker filled with distilled water was attached to the duplicate apparatus so that the transpirational loss of water from the plants might be compared directly and simultaneously with the loss by evaporation from a free water surface of nearly constant level. The results of this experiment are indicated in Figure 5. It may be seen from this figure that transpiration was greatly accelerated by the light of day, while evaporation was not thus affected.

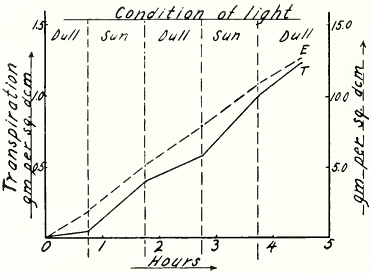

Fig. 6—Effect of varied light intensities upon transpiration and evaporation. T=transpiration from potted bean plants. E=evaporation curve for a free water surface.

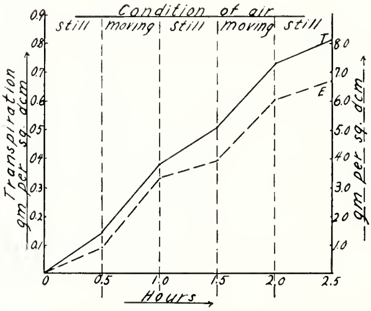

Fig. 7—Effect of still and moving air upon transpiration and evaporation. T=transpiration curve. E=evaporation curve.

Tests concerned with the effects upon transpiration and evaporation of changing light intensities and of still and moving air were also performed in the laboratory. In spite of relatively short experimental periods, appreciable differences were recorded between the rates of transpiration in bright and dull light, and in moving and still air. Figures 6 and 7 indicate the relationships found in these experiments.

Summary. A simple and inexpensive transpirometer is herein described which has proved useful for tracing the course of transpiration over extended periods of time, for demonstrating relative rates of transpiration during day and night, for indicating the effects of still and moving air and of bright and dull light on transpiration, and for securing comparisons between the water losses by transpiration and by direct evaporation from a free water surface.

A NOTE ON *PASSIFLORA LUTEA* L.

ROBERT HESSLER, Indianapolis

The native Yellow Passion Flower, *Passiflora lutea* L., is found only in a few localities in the southern counties of Indiana, according to Coulter's catalogue; counties mentioned are Monroe, Fayette and Jefferson. It is a vine that according to the books reaches a height of three to ten feet.

A few years ago I found several seedlings partly shaded by a beech tree on the western edge of Marion County, near Clermont. Two were transplanted into my garden; one died, the other had a struggle for existence. For the first few years there was little development; besides one main shoot there were at times small shoots which did not survive. This year (1931) there were at first three vigorous shoots, and later on three more, which, however, did not survive. The underground movement varied from six to ten inches.

Stakes six feet long were supplied, and when two of the vines reached the top they were pinched off, the result being only a few flowers. The third stake was extended to twelve feet, and by midsummer the upright vine was eleven and one-half feet long, with about one hundred flowers, followed in time by many seed pods. I have the data and figures among my garden notes. Twice, a teaspoonful of old bacteriologic peptone was applied. (This may account for this being a "Giant Plant.")

On October 2, when the thirty seed pods were ripe, I cut and dried the upper five and one-half feet. The seed have been distributed and I put up the rest in packages. Those interested in rare native plants, or who care to experiment, are welcome to them.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

PLASMOLYSIS

RICHARD KING, Maryland

The word "plasmolysis" was first used by De Vries.[1] Certain cells, as those of the primary meristem of the root of *Vicia faba*, quickly die when plasmolyzed.[2] Other cells, however, when plasmolyzed with suitable solutions of sugar, may remain living from a few days to several weeks.[3] Again, the cells of some species of Spirogyra are killed in only a few hours when plasmolyzed. Thus, in the case of what we may term artificial plasmolysis, all degrees of differences in the length of life of a cell are noticeable after plasmolysis. But there are cells also in which plasmolysis is naturally produced.[4] An example of such natural plasmolysis is to be seen in the Conjugatae, as for example in Spirogyra, when conjugation is taking place.[4] In this case, each gamete contracts considerably, due to loss of water; and to such an extent that after the complete fusion of the gametes, the resulting body is about the size of one of the original gametes. Hence a comparatively large amount of water escapes in this process without causing the death, or even apparently of any visible change, in the character of the membrane. In *Spirogyra nitida*, as has been shown by De Bary, one cell may conjugate with two other cells; so that here also the resulting zygospore formation is preceded by the expulsion of a considerable quantity of water. The loss of water through a membrane in a natural way is also to be seen in those cases in which cell formation occurs, as in rejuvenescence (in *Stigeoclonium insigne*, for instance) ; and which is shown in those cases of rejuvenescence where the production of the zoogonidia in Oedogonium occurs. There are other instances of this phenomenon, but it is to be observed that such direct cell formation is restricted to reproductive cells of various kinds. There is a good deal of speculation concerning rejuvenescence which does not especially concern us here; but equally cloudy also is the reason for the escape of water through the living membranes mentioned, aside from space in Spirogyra, for example. Also interesting and unanswered are questions concerning the changes in the living membrane which allow for a time the expulsion of water, and hence the marked contraction which is so conspicuous, especially in Spirogyra. Our problem, however, does not concern itself directly with cases or instances of natural plasmolysis, so called; but only to cite these by way of comparison. It will also be noted in the case of natural plasmolysis that the cell or cells concerned are not killed or apparently injured by such a change, however great that may be, or however long or short the time involved. The length of time involved in a natural

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[1] De Vries, Hugo—Untersuchugen über die mechanischen Ursachen des Zellstrechung 1877 p. 10.

[2] Pfeffer, W.—Druch-und-Arbeitsleistung durch wachsende Pfanzen 1883 p. 307.

[3] Klebs, G.—Unters, a.d. Bot. Inst. in Tübringen, 1886, Bd. 2, p. 504.

[4] Pfeffer, W.—Physiology of Plants, Trans. by Ewart 1897 vol. 1, p. 143.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

plasmolysis is much greater than in those experiments where artificial plasmolysis is produced, but other very decided differences are those as above stated, in which certain artificially plasmolyzed cells die quickly, others in a few hours, while still others may live for weeks under suitable conditions. Where, however, cells are plasmolyzed artificially, the death of such cells always occurs sooner or later.[5]

The object of this paper is to show not only the character of the solutions that may be used most successfully on the plants studied, but especially to ascertain the length of life of these plants when artificially plasmolyzed in the various solutions.

Plants Used. The plants used for the experiments were: *Elodea canadensis, Cladophora glomerata, Pinnularia viridis* and *Spirogyra crassa*.

Solutions Used. In this study, four solutions were used: namely, cane sugar, sodium chloride, potassium nitrate, and magnesium sulphate.

EXPERIMENTS AND RESULTS WITH THE VARIOUS PLANTS

Elodea canadensis All of the four solutions above mentioned were used in the experiments on *Elodea canadensis*. In the first test, the cells of the leaves were able to recover after being plasmolyzed for twenty-five minutes in a twenty per cent solution of cane sugar; while the cells of one leaf recovered after being plasmolyzed for forty-five minutes. Observations of still another leaf (this one a leaf from a plant that had been obtained from the creek at a more recent time than the two preceding specimens) shows that it withstood the plasmolyzed state in the twenty per cent solution of cane sugar for one hour and fifteen minutes and was still able to deplasmolyze. These three results will show the variability of the different individual leaves of the specimens on hand and of the individual plants themselves.

Thus, after being plasmolyzed in a twenty per cent solution of cane sugar for one hour and forty-five minutes, the cells of the *Elodea canadensis* leaves experimented with were killed.

It was found that those cells in the midrib, those cells bordering the midrib in the upper half of the leaf, and those cells of the lower half of the leaf were the only cells to plasmolyze to any extent in the solution used; while the remaining cells in the leaf were unplasmolyzed, or were plasmolyzed only slightly. Thus, the O. G. of the cells of the *Elodea canadensis* experimented with equalled on the average a twelve per cent solution of cane sugar.

A similar test was conducted with a two per cent solution of sodium chloride. The specimen was left in the solution for five minutes, but failed to recover from the plasmolyzed state. A ten minutes exposure in a 1.6 per cent solution of sodium chloride, however, proved successful; but an additional five minutes exposure proved fatal to the cells, as they failed to resume the natural state.

When placed in an eight per cent solution of potassium nitrate for five minutes, the cells were plasmolyzed, but recovered. They failed to even show plasmolysis after an additional fifteen minutes in this same solution. This, perhaps, may be explained by the fact that a thin film of water still adhered to the leaf when it was deplasmolyzed; and in the next exposure to the potassium nitrate, the solution was unable to penetrate the cells for a time. A third attempt of two hours in the potassium nitrate caused plasmolysis and death.

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[5] Pfeffer, W.—Physiology of Plants Trans. by Ewart 1897, vol. 2, p. 258.

In testing with a ten per cent solution of magnesium sulphate, the cells of *Elodea canadensis* were able to recover after being in the solution for ten minutes, but were killed after an additional ten minutes.

Cladophora glomerata. The four solutions were also used in the tests on *Cladophora glomerata*, as in the tests on *Elodea canadensis*.

The first tests were made on specimens that had been kept in the laboratory for several days.

A thirty-four per cent solution of cane sugar was able only to cause a slight degree of plasmolysis, while a thirty-eight per cent solution brought on a good state of plasmolysis. In the latter solution, the cells were able to undergo plasmolysis for thirty minutes and recover, but were killed after two hours in the same solution.

A five per cent solution of sodium chloride was required to plasmolyze the *Cladophora glomerata* cells, but they continued to live after having been in the solution for one hour, but an additional ten minutes was sufficient to kill those that had been in the laboratory for some days.

The second set of tests on *Cladophora glomerata* was conducted on fresh specimens just brought into the laboratory in order that we might compare the response of the cells in fresh plants with those in plants which had been in the laboratory for several days.

The cells of the fresh *Cladophora glomerata* were able to recover from being in a six per cent solution of sodium chloride for two hours, but were killed after a four-hour exposure. In certain other specimens just brought into the laboratory, the plasmolyzed state was able to be brought about in a forty per cent solution of cane sugar, and it was found that the cells were still alive after exposure of one hour and of two hours and thirty minutes, but were killed when left for a longer period of time in the solution.

In testing with an eighteen per cent solution of magnesium sulphate, it was found that the cells could withstand the solution for three hours and still recover from the plasmolyzed state, but were killed when allowed to remain four hours.

Several tests had to be made when solutions of potassium nitrate were used. One test, however, was able to show that the cells deplasmolyzed slowly after an exposure of one hour and thirty minutes in a sixteen per cent solution, but were killed when left for twenty minutes longer. The degree of plasmolysis varied from cell to cell, and from extreme plasmolysis to none at all.

Pinnularia viridis. Only two of the solutions were used in the tests on *Pinnularia viridis*—cane sugar and potassium nitrate.

Much difficulty was encountered in obtaining plasmolysis and recovery, and it was possible throughout the experiments to observe only a very few plasmolyzed forms. These were obtained in a twenty per cent solution of cane sugar and in a five per cent solution of potassium nitrate.

When exposed to the cane sugar solution, the movement of the diatom was stopped during the plasmolyzed state, but was slowly resumed after recovery. It was further seen that movement was also stopped in higher concentrations than twenty per cent—as, for example, twenty-five per cent, which was the O. G. of the specimens experimented on. Isosmotic solutions stopped the movement.

The results of the tests with the solutions of potassium nitrate were similar to those obtained with the cane sugar solution. Movement was arrested during the plasmolyzed state in the five per cent solution and was resumed again after recovery.

Spirogyra crassa. The four solutions were used for the tests on *Spirogyra crassa* as for *Elodea canadensis* and *Cladophora glomerata.*

Of *Spirogyra crassa*, both fresh specimens (i. e., those which were just brought into the laboratory) and other specimens, which had been in the laboratory for several days, were used. The O. G. of the specimens tested equalled, on the average, eleven per cent of cane sugar. Individual specimens, or even certain cells, showed at times considerable variation from this per cent.

In cane sugar, the cells lived one hour and thirty-five minutes when plasmolyzed; when plasmolyzed in magnesium sulphate, they lived one hour and seven minutes; when potassium nitrate was used, they lived forty-five minutes; and when in the solution of sodium chloride, the cells were able to survive, on the average, about twenty-one minutes.

Conclusions. In summing up the results of these tests in which I have attempted to show the character of the solutions that may be used most successfully on the plants, and also to ascertain the length of life of the plants when artificially plasmolyzed in the solutions, I have found cane sugar[6] to be the least harmful of the four solutions used, since the specimens were able to undergo the plasmolyzed state for a longer period in the cane sugar and yet survive than in any of the other solutions. While magnesium sulphate was the next least harmful, with potassium nitrate a close third; since the solutions of magnesium sulphate and potassium nitrate averaged about the same in their effects on the plants. Sodium chloride was found to be the most harmful of the four solutions used.

As to the second point which I have attempted to bring out, I have found that *Spirogyra crassa* is the least resistant of the plants tested, and also, as was seen in *Elodea canadensis* and *Cladophora glomerata,* that fresh specimens which were just taken from the creek were more vigorous and resistant than specimens which had been kept in the laboratory for some time.

In order to arrive at the safe averages that I have obtained in this series of tests, it was necessary to test a great number of plants in the various solutions, so that I might overcome the difficulties encountered.

I wish to express my deep appreciation of the kind assistance and advice of Dr. F. M. Andrews, professor of plant physiology, Indiana University.

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[6] Beck, W. A.—Cane sugar and potassium nitrate as plasmolyzing agents. Protoplasma, 1926, 1: 62.

(Beck found cane sugar to be superior to potassium nitrate for his work in plasmolysis.)

GROWTH IRREGULARITIES IN HYBRID FREESIAS INDUCED BY X-RAYS

W. P. MORGAN, Indiana Central College

In recent years much attention has been given to the use of X-rays and radium in the production of new plant and animal types through the effect of these potent rays on the genetic mechanism. In order to test the effect upon Freesias, seeds, flower buds and corms of a recently introduced commercial variety known as Elder's Giant White were subjected to X-rays. The choice of this variety for experimentation was due to the fact that much data concerning its genetics and cytology had already been compiled. Although it is too early to report any observed effect upon the heritable characters of this plant it seemed sufficiently interesting to present some observations made upon irregularities of growth induced by the X-ray exposures.

Corms of similar size and form were carefully selected and these placed in groups of five in small paper bags. Since the corms were of average size (slightly less than five-eighths inch in diameter) it was possible to fold the bags so as to keep the material to be treated in a single layer. In this condition these small parcels of corms were arranged beneath the X-ray tube. The apparatus used was a modern machine normally employed in X-ray therapy and was operated by a professional technician.[1] The first lot of ten groups was placed at twenty inches from the target and exposed in two-minute intervals up to twenty minutes at 105 K.V.—30 M.A. with a 1 mm. aluminum screen. In the second lot no screen was used and the exposure was in three-minute intervals up to twenty-one minutes with a distance from the target of sixteen inches at 105 K.V.—30 M.A. Each group of five corms was planted in a six-inch clay pot and at the same time untreated controls were planted under identical conditions. Careful cultural attention was given throughout the entire growing season. The greenhouse night temperature was held at about forty-eight degrees F. with the usual rise during warm, sunny days.

Due to an irregularity in the storage of the corms from which lot number one was chosen it was decided to abandon this data entirely, therefore the following observations refer only to plants produced by the second lot of corms. This lot was planted on November 15, 1930, and was examined daily. The following representative record of growth was that taken on December 22nd. The measurements of plants were taken from the surface of the soil to the top of the highest leaf.

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[1] The author is indebted to Dr. W. E. Pennington for his assistance and in the use of his X-ray equipment. The intensity of the dosages was based upon the helpful suggestions of Dr. A. F. Blakeslee of the Carnegie Institute of Washington.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

Control pot: all five showing with heights varying from 3/16 to 1¼ inches.
Pot No. 1 (3 min. exposure): three plants up one 5½ inches, one 4½ inches and one ⅝ inch.
Pot No. 2 (6 min. exposure): due to an injury to one of the corms only four were planted. Two plants up, both 2½ inches.
Pot No. 3 (9 min. exposure): four plants up, two 1¼ inch, two ⅝ inch.
Pot No. 4 (12 min. exposure): four plants up, all about ⅜ inch.
Pot No. 5 (15 min. exposure): four plants up, one ⅞ inch, three ⅜ inch.
Pot No. 6 (18 min. exposure): three plants up, two ¼ inch, one ⅛ inch.
Pot No. 7 (21 min. exposure): two plants up, both 3/16 inch.

Final germination records showed that all corms grew with the exception of those in pots No. 6 and No. 7. In these the final count showed four corms grew in No. 6 and only two in No. 7 Figure one shows the relative growth of this lot and its control on March 28, 1931. As indicated in the size of the buds of No. 1 and No. 2 these pots showed mature blossoms a few days before those on the control plants.

One item that attracts attention in figure one is the greater number of plants in pots numbers 1, 2 and 3 than in the control (N), in spite of the fact that all corms were carefully graded as to size. In the control each corm produced a single plant while as many as five "shoots" were produced by a single X-rayed corm. Although it is not unusual for large corms of Freesia to occasionally produce two or three shoots it was demonstrated by many pots planted from the same stock which supplied the experimental material that only seldom did a corm produce more than a single plant. Some explanation of the increase in number of shoots may be gained from the examination of a Freesia corm with its husk removed. Figure two shows top and side views of a whole corm similar to those used, also a bissected corm. In each of these sketches is shown the buds from which grow the "shoots" just mentioned. Usually the top one germinates while the others are abortive. A careful ex-

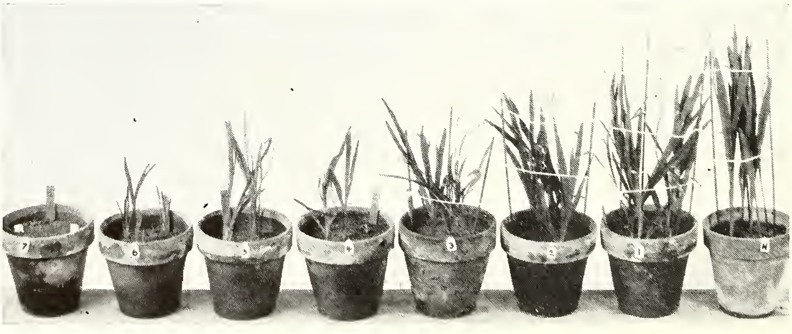

Fig. 1. Growth produced by X-rayed corms compared with the control N. Intensity of dosage was graduated from No. 1 to No. 7. Note the increase in number of plants produced by the corms of the lower X-ray dosage.

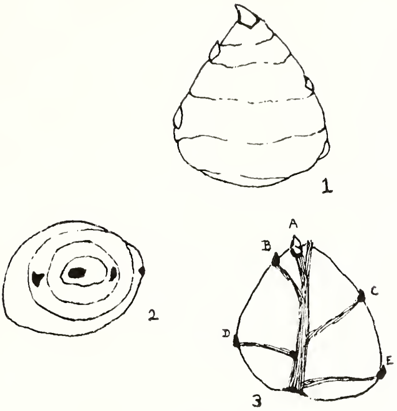

Fig. 2. Sketches of normal Freesia corms. No. 1 is lateral view with husk removed to show primary and axillary buds. Upper view of same corm is shown at No. 2 while No. 3 is the corm bissected to show the above features.

amination showed that not only did this top bud grow in the X-rayed corms but the lateral buds were also stimulated into growth. That this was not alone due to the injury to the primary bud was demonstrated by purposely mutilating corms in removing this upper bud. Such corms seldom produced more than a single shoot from their lateral buds.

As indicated in the early growth records the X-rayed corms that started to germinate immediately after planting made more rapid

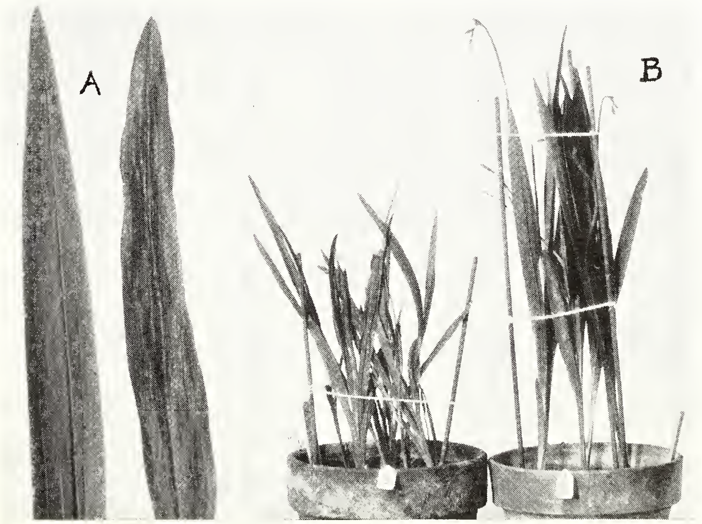

Fig. 3. A shows normal leaf besides one taken from a plant produced by an X-rayed corm. B shows the taller plants in the control compared with plants from corms X-rayed nine minutes. Note increase in *number* of plants in the pot containing the X-rayed bulbs.

progress than the controls. It is quite possible that a lower dosage would have given an accelerated growth without noticeable injury. Just what effect X-ray dosage would have upon the corm when it was in the first part of the dormant period has not been determined. As shown in figure one the higher dosages had a distinct retarding effect which very nearly reached the lethal point in No. 7 (XR 18).

In figure 3B the plants from the X-rayed corms lack the upright growth and straight leaves characteristic of this variety as shown on the control (N). Figure 3A is a close-up view of two leaves. These were taken from the plants shown in figure 3B. The plant from pot No. 3 was suggestive of "crepe" cloth or paper and this condition involved the structure of leaf, stem and flower. The condition of the leaves in the pots where the corms had a higher dosage were similar except in the higher degree of deformity while those of the lower dosage were more nearly normal. The irregularity of texture was accompanied by a disturbance in the distribution of chlorophyll producing light and dark areas. As a result of these irregularities in growth the leaves and stems became curled and twisted, and the flowers split and deformed. In spite of these conditions seed was set on the plants in all pots except No. 7 which produced very little more growth than shown in figure 4A.

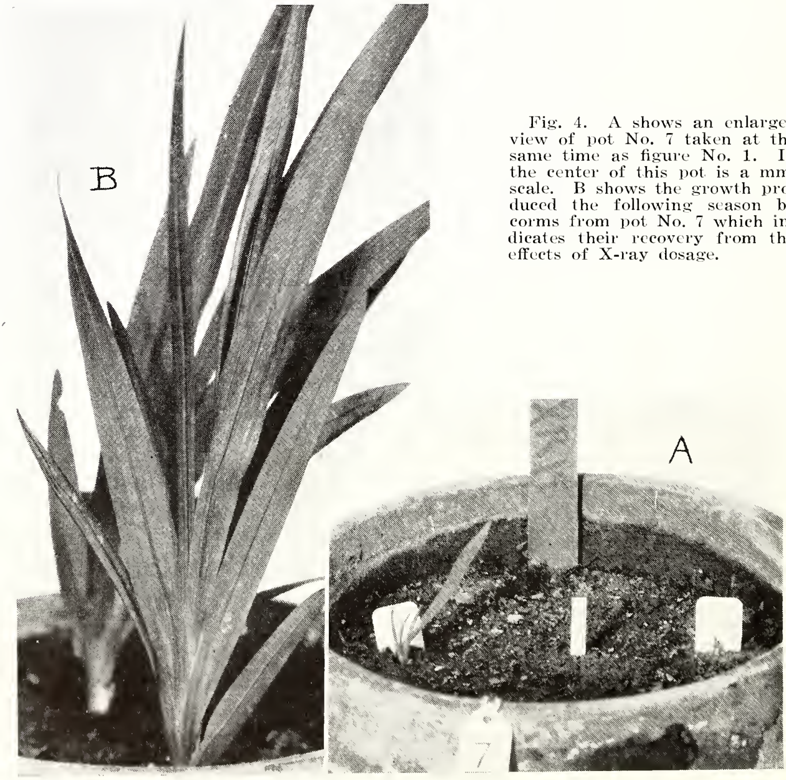

Fig. 4. A shows an enlarged view of pot No. 7 taken at the same time as figure No. 1. In the center of this pot is a mm. scale. B shows the growth produced the following season by corms from pot No. 7 which indicates their recovery from the effects of X-ray dosage.

All plants from the X-rayed corms and their control were kept carefully covered and their blossoms self-pollinated. A record of the seed production, which is never high in this variety, follows: Control pot, 120; pot No. 1, 225; pot No. 2, 186; pot No. 3, 84; pot No. 4, 157; pot No. 5, 58; pot No. 6, 5. The germination of these seeds appeared to be normal, although a record of their growth will not be complete until after the spring of 1933 since seedlings of this variety seldom bloom the first season. To date none of the tiny seedlings show the growth irregularities present in the parent plants.

The resulting corms and cormlets produced in each of the pots described above were carefully saved and planted early in the autumn of 1931, and have made nearly normal growth. Some of the first leaves from the corms of pots No. 5, No. 6 and No. 7 showed some "creping" and curling but this condition has practically disappeared in the later leaves. Figure 4B shows the plants resulting from the two small corms of pot No. 7. This indicated nearly a complete recovery from the effect of the X-ray treatment which was severe enough to kill three of the five corms planted in pot No. 7. Whether any effect will be noted in later growth or blooming of these plants is not known. (Photograph used in 4A was made December 18, 1931).

In addition to the X-raying of the corms both seeds and developing flower buds were subjected to treatment with these rays. In 1930 three lots of seed saved from self-pollinated plants of Elder's Giant White were exposed ten, sixteen and twenty minutes respectively at 105 K.V.—30 M.A., twenty inches from the target with a 1 mm. aluminum screen. These germinated normally with no irregularities noted during the growing season. During the first part of the present season (fall 1931) several plants resulting from corms produced by these seedlings showed leaf irregularities similar to those described above. This condition was found only on plants from the seed that had been exposed sixteen and twenty minutes. It is probable that higher dosage would have produced a pronounced effect uon the seedlings. No explanation can be offered for the irregularities being absent in the seedlings but appearing in plants from corms produced by the seedlings, except that the affected individuals may have been overlooked since the whole lot was quite frail due to the late planting date.

On February 28, 1930, four pots of Freesia plants in bud were exposed four, seven, ten and thirteen minutes respectively at 105 K.V—30 M.A. The flower buds were placed twenty-five inches from the target. A 1 mm. aluminum screen was used. No effect on later growth or blooming was noticed, however the young plants resulting from their seed (by self-pollination of their blossoms) showed leaf deformity similar to that resulting from the X-rayed corms. When the corms produced by the above seedlings were planted this season (fall 1931) they showed only a few of the first leaves to have the characteristic "creping" and deformity. Later leaves appeared to be normal.

Since no histological study was made of the affected plants it was not certain what effect upon the microscopical structures had been produced by exposure to the X-rays. The appearance of the affected leaves suggested that there was a disturbance in the rate of growth in localized areas, and in the distribution of the chloroplasts or the formation of chlorophyll. The general effect of X-ray treatment in low dosage seemed to result in an acceleration in the rate of growth and in the stimulation into growth of structures that otherwise would have become abortive. With the increase in intensity of the dosage the acceleration was lost and the rate of growth became retarded, approaching the lethal point as in pot No. 7. That the Freesia plant was able to recover from this disturbance of its somatic structure seemed to be indicated when figure 4A and B were compared. Just what this reorganization was that took place during the formation of the corm and subsequent growth after a period of dormancy is not known. No effort has been made in the present paper to deal with any genetic disturbance resulting from the effect of X-rays on the germinal substance of the Freesia.

STUDIES ON *BERBERIS VULGARIS* AND RELATED SPECIES: I. ON SEED GERMINATION AND THE SURVIVAL OF SEEDLINGS OF *BERBERIS VULGARIS* IN MONROE COUNTY, INDIANA

David M. Mottier, Indiana University

In September, 1929, a series of studies on the common barberry, *Berberis vulgaris L.* was begun with the hope of their continuance through a number of years. The studies as planned include the germination of seeds in the greenhouse and in the open, the survival of seedlings in the open together with morphological and cytological investigations. It is intended to extend the morphological and cytological studies also to *B. Thunbergii* and perhaps to other species. Other features of interest may be included.

The results thus far obtained on the seed germination and on the survival of seedlings of *Berberis vulgaris* L. are given in the following paragraphs.

Germination of Seeds. The seeds used in the studies were supplied by the U. S. Department of Agriculture through the office of Mr. Wayne E. Leer, State Leader in barberry eradication in Indiana.

Germination experiments were made in the greenhouse and in the open. In the open, plantings were made in full sunshine in both poor and well fertilized soil, in an open thicket, and in a virgin beech-maple forest.

In the greenhouse the seeds were sown in flats. The conditions in the greenhouse were such as are usually maintained in a hot house used for general purposes in connection with a department of botany.

The results secured from the seed pans may be shown from the data as given in the following:

Flat No. 25. In this flat 750 seeds, removed from the fruits, were sown in rich woods earth on September 20, 1929.

Oct. 29, 1929—31 seedlings appeared above ground
Nov. 8, 1929—12 additional seedlings were up
Nov. 19, 1929— 3 additional seedlings were up
Dec. 20, 1929—17 additional seedlings were up
Jan. 29, 1930— 4 additional seedlings were up
Feb. 28, 1930— 4 additional seedlings were up
Mar. 28, 1930— 5 additional seedlings were up
May 15, 1930—14 additional seedlings were up
May 30, 1930— 1 additional seedling was up
After May 30 no seedlings appeared.

From the 750 seeds in this flat a total of 91 seedlings appeared above the surface of the soil, or a viability of 1.2 per cent. The germination extended over a period of 8 months and ten days.

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Flat No. 23. 500 seeds were sown in this flat Oct. 4, 1929.

Nov. 8, 1929— 6 seedlings were above ground
Nov. 21, 1929— 1 additional seedling appeared
Dec. 20, 1929— 8 additional seedlings appeared
Jan. 29, 1930—11 additional seedlings appeared
Feb. 28, 1930— 3 additional seedlings appeared
Mar. 28, 1930— 4 additional seedlings appeared
May 15, 1930—12 additional seedlings appeared
May 30, 1930— 1 additional seedling appeared

After May 30 no additional seedlings appeared. Of the 500 seeds in this flat 46 germinated or .92 per cent. An examination of the soil in both flats after another month revealed only the remains of decayed seeds.

From the foregoing it will be seen that germination was poor and it extended over a period 7 months and 26 days.

In order to determine whether a small opening made in the seed coat by means of a file, would have any effect upon germination, 500 seeds, each with a small slit-like opening thus made in the seed coat, were sown in a flat on October 2, 1929, and kept under green house conditions. Of these not a single seed germinated; all decayed.

Survival of Seedlings in the Open. In order to determine the survival of seedlings in the open, sowings were made in beds exposed to different conditions of soil, illumination, and shade.

Two beds were shown side by side in the open under full sunlight in a clay-loam soil, one being well fertilized with barnyard manure and the other unfertilized. The fertilizer was well rotted and thoroughly worked into the soil before the seeds were planted. In the fertilized bed 500 seeds were planted about one-half inch deep on July 20, 1929. On October 29, 1930, there was not a single survivor in this bed. Of these seeds only a few germinated.

In the same bed 100 fruits were planted at about the same depth. On October 29, 1930, there was but one surviving seedling. As the fruits average about two seeds each, there was under the conditions mentioned, one survivor from the 200 seeds.

In the unfertilized bed 500 seeds were also sown on July 20, 1929. From these seeds there were two survivors on October 29, 1930.

In this bed 100 fruits were also planted on October 5, 1929. On October 29, 1930, there were three survivors.

The two beds just mentioned were kept weeded, but the soil was not cultivated. On October 1, 1931, there were but two survivors in the unfertilized bed, the larger being ten inches high, and one survivor in the fertilized bed.

In the two beds above mentioned second sowings of 500 seeds were made in each on October 29, 1930. On October 1, 1931, there were 8 survivors in the fertilized bed and 10 in the unfertilized bed. From the thousand seeds, 18 survivors resulted. All of the plants are small, measuring two to three inches in height.

From the 2,400 seeds planted in the two beds a total of 18 seedlings were present in October, 1931.

Beds in the Thicket. The soil is a clay-loam and poor. The beds in the thicket sloped somewhat towards the north and the shading was much less than that under a full canopy of foliage, such as occurs in a beech-maple forest. From 1,000 seeds sown on October 14, 1929, there was a survival of 20 seedlings on October 29, 1930. On October 1, 1931, 18 plants were present, a little better showing than in full exposure to the sun. They are small and apparently stunted, the largest being four inches tall and unbranched.

Survival in Virgin Forest. On November 27, 1929, 1,000 seeds were sown in a bed in a beech-maple forest. In preparing the bed the dead leaves were raked off and the 1,000 seeds sown in rows and covered one-half inch deep with the rich leaf mould, after which a light covering of half-decayed leaves was spread over the bed. The bed was in the shade of a full canopy of the beech-maple forest.

Germination was poor. On November 1, 1930, seventy-five seedlings survived. A few of these had been lifted almost out of the ground as a result of freezing. Of these seventy-five survivors thirty only were present in the bed October 1, 1931. They had made a slow growth, the most vigorous having attained a height of about six inches.

On April 8, 1931, in a similar bed near the locality of the former, 3,000 seeds were sown, and on October 1, 1931, there were but seven survivors. They are all small, weak plants.

From the 7,400 seeds sown in the open under the conditions mentioned in the experiments a total of 73 plants resulted as survivors.

The shaded condition of thicket and forest seemed to be more favorable for the survival of *Berberis vulgaris* than open ground.

It will be recalled that the drought and heat of the growing season of 1930 were unusually severe, and only the most thrifty seedlings located in the most favorable natural environment could survive.

Pot Cultures of Seedlings in Greenhouse. From seeds sown Sept. 20, 1929, resulting seedlings were transplanted to six-inch pots November 20, 1929. On March 28, 1930, the first axillary dwarf branch developed from the axil of the 19th leaf. This leaf was reduced in size and had long spines typical of the species. The 20th leaf was almost reduced to spines, while the 21st leaf was completely changed to spines.

On June 15, 1930, two long branches had developed from older nodes of the primary stem just above the surface of the ground. On October 15, 1930, the primary shoot had attained a height of about four feet. The two long branches present on June 15 were almost three feet tall. During the summer three new long branches developed, two from the primary axis below the insertion of those appearing on June 15, and the third was a branch from one of the secondary long shoots. The foregoing record pertains to the most thrifty of pot grown plants. During the winter months of 1930 the potted plants were placed in the cold room of the greenhouse. In the spring of 1931 they were transplanted to the open in the garden. During the summer they grew into bushy specimens, the largest having 15 long branches. The branching took place near the ground. A number of the branches arose from the primary axis, while others sprang from the branches of the second order.

The order of development of the plants grown from seed sown in the open was the same as in the pot grown specimens.

Tischler[1] in his rather complete account of the development of *Berberis vulgaris* from the seed states that, during the first year short shoots only developed, the long branches appearing first in the second year. The rapidity and extent of growth attained the first year or season will depend upon the conditions facilitating growth. Even in the pot grown plants a considerable difference in the rapidity of growth was observed, and in the open the wide variation in the growth made by different plants is very apparent.

Development of Adventitious Shoots from the Roots. In addition to the well formed root system of the three-year old barberry bush, subterranean shoots develop, according to Citerne as reported by Tischler, which bear cataphylls and send up above the ground leafy shoots. "Ausser den Wurzein giebt Citerne noch an 'rameaux souterrains enracinés, couverts de bractèes, qui se redressent et s'epanouissent en rameaux feuilles aprés un traject plus ou moins long dans de sol'." In order to determine whether these subterranean branches arise from the stem or from roots, Tischler made an experiment as follows:

"Von einem dreijährigen Stämmchen schnitt ich Mitte Januar 1902 die ganzen oberirdischen Teile und selbst die von Nebenwurzeln freie obere Partie der Wurzel ab. Schon in den ersten Tagen des März war (bei Warmhausculturen) an der oberen Wundfläche eine grosse Laubknospe angelegt, die bereits anfing, ihre Blätter auszutreiben, und ausserdem noch eine weitere unentwickelte Knospe. Als ich die Wurzel aus der Erde herausnahm, endeckte ich an vier Stellen an den Wurzeln ansitzende Laubknospen, zum Teil in ziemlicher Tiefe im Boden. Die oberste lag 5½ cm., die anderen 6, 8 und 10 cm. von der Erdoberfläche entfernt, während die Wurzeln selbst bis zu einer Tiefe von 16 cm. reichten. An drei von diesen vier Orten waren mehr als eine Knospe, gerade wie an der oberen Wundfläche ausgebildet, zum Teil auch schon ein wenig ausgewachsen. Diese Adventivbildungen kommen aus der Cambialregion der Wurzel heraus, wie dies gans normal ist." The internodes of subterranean branches ("rameauz souterrains") of Citerne, varied in length, the longest not exceeding 10 mm., and possessed small, spirally arranged cataphylls.

Tischler's experiment demonstrated the development of adventitious buds from the roots of a three-year old plant when all the parts above the soil, including that portion of the tap root which was free from lateral roots were cut away.

It is to be noted that the subterranean buds which appeared in Tischler's experiment developed from roots in which secondary thickening had begun and upon a root system of a plant from which the stem or stems had been cut away. Whether *Berberis vulgaris* will develop adventitious shoots from the roots under normal conditions is unknown at present to the writer.

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[1] Tischler, George. Die Berberidaceen und Podophyllaceen. Versuch einer morphologisch-biologischen Monographie, Bot. Jahrb. Eng. 31:596-727. 1902.

MIXED CULTURES OF BACTERIA AND FUNGI

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The bacteriologists rightfully condemn the fungi as frequent and undesirable weeds contaminating their cultures. It is equally true, however, that those working with fungi must exercise every precaution to keep bacterial weeds from their fungus cultures.

In attempting to make pure culture isolations of fungi from almost any plant material but more especially from material such as roots with adhering soil, bacteria are the most troublesome components of the mixed culture which often results from the first attempt at isolation.

Plate cultures of fungi often become contaminated with various organisms either because of the ill fitting lids of the petri plates or through careless manipulation. Bacteria constitute one of the most frequent contaminations; possibly coming in on dust particles.

Separation of the components of a mixed culture may be easy or difficult depending both upon the nature of the components and upon their distribution. It is not especially difficult to secure a pure culture from a mixture of two or more fungi. Differential growth and mutual antagonisms usually separate colonies of fungi in such a manner that pure cultures may be made by transferring the appropriate mycelium from its delimited region of growth in the culture. Many times bacteria remain in separate colonies sharply differentiated from the surrounding fungi. In such cases pure cultures of the fungi are as readily obtained as when fungi alone may be present in the culture. A more difficult situation arises when one has to contend with a bacterium of the "spreader" type. Such an organism grows so rapidly that it crowds into and under the fungus growth. Even with such a bacterial contamination the cultures may be differentiated by careful manipulation. The most difficult type of bacterial contamination however is one which tends to keep pace with the growth of the individual hyphae of the fungus. The hyphae growing next to the surface of the substrate often lie in minute groves in the substrate. These grooves are doubtlessly produced by the enzymatic activities of the fungus. The bacteria inhabit these grooves probably gathering nutrition from the fungus digested materials of the medium. It would seem as if a symbiotic relationship existed between the two organisms. Such combinations cannot be separated by differential growth and other more strenuous means such as the use of an acidified medium must be adopted. An intimate association of fungus and bacteria such as just described produces a marked effect upon the nature of the fungus development. In most cases there is a complete suppression of aerial mycelium. The hyphae take on a greasy appearance as viewed by the naked eye and frequently the presence of the bacteria cannot be detected except by the most careful observation with the highest power of the microscope.

When such contaminations exist in fungus cultures little attention is paid to the bacterial components except to get rid of them. No attempt is made to identify the bacterial organism or to otherwise study it. That such study would yield profitable information must be apparent from the standpoint of the antagonisms that may exist, from the standpoint of the possible symbiotic relationships, and from the effect on the physiology and the morphology of the fungus. In many cases we might regard our fungi as being diseased by the bacteria. The first step in the conquest of any disease is to understand the causal agent and its relationship to the organism diseased.

The research recorded in this paper is an attempt to analyze the relationships that exist between known bacteria and known fungi and the effect of such relationships upon the growth of the fungus.

A number of pure cultures of bacteria were secured from the Department of Bacteriology at Purdue University.

Potato dextrose agar was used as the medium upon which to carry out the experiments. This was chosen because most fungi grow well upon this medium and we carry our stock cultures of fungi upon potato dextrose agar. It is true that potato dextrose agar is not the most desirable medium upon which to grow some of the bacterial cultures used but the problem is being studied from the standpoint of routine fungus technique and not from the standpoint of the best technique for bacterial culture.

Tubes of P. D. Agar were melted and permitted to cool to 45°C. At this temperature they were inoculated with the appropriate bacterial culture and the inoculum was mixed with the agar of the tube by rotation of the tube between the hands. Plates were poured from the agar so inoculated. Six hours after pouring the plates each plate was inocu-

TABLE I

Experiments Upon the Growth Rate of *Basisporum Gallarum* as Affected by Various Bacteria. Growth of Fungus Colony Recorded in mm.

Combined with:	48 hrs.	72 hrs.	Increm't increase	96 hrs.	Increm't increase	Remarks
Ck.	36 mm.	74	38	90	16	
B. mycoides	37 mm.	72	25	90	18	
B. subtilis	33	60	27	78	18	Bacteria follow hyphal growth
B. mesentericus vulgatus	2	2	0	4	2	
Orange sarcina	43	63	20	83	20	
Yellow sarcina	44	70	26	90	20	
Strep. lactis	26	51	25	82	31	Bacteria follow hyphal growth
Ps. campestris	0	57	57	90	33	Growth scanty
B carotovorus	18	29	9	42	13	Fungus excessively branched and somewhat distorted
B. megaterium	27	45	18	64	19	Bacteria follow hyphal growth
Inhibitor*	0	0	0	0	0	

TABLE II

Experiments Upon the Growth Rate of *Sclerotium Rolfsii* as Affected by Various Bacteria. Growth of Fungus Colony Recorded in mm.

Combined with:	48 hrs.	72 hrs.	Increment increase	96 hrs.	Increment increase	Remarks
Ck.	22	35	13	64	29	
B. mycoides	24	54	30	63	9	
B. subtilis	19	46	27	67	21	
B. mesentericus vulgatus	0	0	0	0	0	
Orange sarcina	0	16	16	34	18	
Yellow sarcina	0	28	28	42	14	
Strep. lactis	0	16	16	37	21	
Ps. campestris	0	10	10	32	22	Growth scanty and submerged
B. carotovorus	0	27	27	46	19	
B. megaterium	0	17	17	35	18	Bacteria follow hyphal growth
Inhibitor	0	0	0	5	5	

lated with a mycelial culture of a fungus. Plates were permitted to stand at room temperature (about 22°C.) for 48 hours and a growth reading of the fungus colony was taken. The colony was measured in mm. and the average of two diameters was taken as the correct measurement of the colony. Three readings were taken at subsequent 24-hour intervals. Tables I, II, and III, designate the bacterial and fungus cultures used and show the total growth and increment of growth of the various checks and fungus cultures grown in intimate contact with bacteria.

The inhibitor mentioned in the above table is a bacterial spreader of the Proteus type having exhibited strong inhibitory effects when grown with fungi.

All cultures including checks were in duplicate or triplicate. Since there was a general agreement in growth rates, figures presented in the column show the average growth rate for all the cultures of any particular combination.

A study of Tables I, II, and III indicates that most of the bacteria used did not materially check the growth rate of the fungus. In fact, stimulatory effects may be indicated in some cases. There was a definite checking of growth whenever *B. mesentericus vulgatus* or the "inhibitor" was used. In order to determine if this effect was general for fungi the experiment was repeated using *B. mesentericus vulgatus* and the "inhibitor" in plate cultures inoculated with the following fungi: *Colletotrichum nigrum*, *Brachysporium* sp., *Helminthosporium gramineum*, *Helminthosporium inaequalis*, *Physalospora cydoniae*, *Botrytis alii*, *Botrytis paeoniae*, *Botrytis tulipae*, *Rhizoctonia* isolated from potatoes, *Fusarium niveum*, *Thielavia basicola*, *Sclerotinia fructigena*, *Pythium deBaryanum*, *Cephalothecium roseum*, and *Penicillium* sp. All of the

TABLE III

Experiments Upon the Growth Rate of *Glomerella Cingulata* as Affected by Various Bacteria. Growth of Fungus Colony Recorded in mm.

Combined with:	48 hrs.	72 hrs.	90 inc.	96 hrs.	90 inc.	Remarks
Ck.	34	39	5	47	8	
B. mycoides	32	41	9	50	9	Bacteria follow hyphal growth
B. subtilis	14	23	9	34	11	Bacteria follow hyphal growth
B. mesentericus vulgatus	4	4	0	5	1	
Orange sarcina	25	34	9	54	20	
Yellow sarcina	26	40	14	54	14	
Strep. lactis	25	39	14	52	13	
Ps. campestris	23	36	13	47	11	Growth scanty and mycelium apparently submerged
B. carotovorus	14	22	8	29	7	Growth restricted and appressed
B. megaterium	19	28	9	37	9	Bacteria follow hyphal growth
Inhibitor	0	0	0	20	20	Growth extremely scanty and hyphae closely appressed to the medium

fungi failed to grow in plates of potato dextrose agar which had been inoculated six hours previously with either *B. mesentericus vulgatus* or with the "inhibitor."

In order to determine whether *B. mesentericus vulgatus* and the inhibitor were capable of inhibiting fungi at a distance, plates were poured with potato dextrose agar medium and were inoculated at their centers with fungi. When the fungus growth was well established, i. e., when the colonies were about the size of a ten cent piece inocula of *B. mesentericus vulgatus* and the "inhibitor" were placed in the same plate on opposite sides of the fungus colony and as far away from the fungus colony as the size of the plate would permit. Three fungi were used in this experiment, viz. *Glomerella cingulata, Sclerotium rolfsii,* and *Basisporum gallarum.* The results were evident after 24 hours. Basisporum was but slightly inhibited by either bacterial organism, the fungus growing over the bacterial colonies. Both the Glomerella and the Sclerotium were inhibited sharply by both organisms. *B. mesentericus vulgatus* proved to be the better inhibitor and exercised its inhibitory influence at a considerable distance from the fungus.

The results of the experiments thus far conducted demonstrate that bacteria vary widely in their powers to check the growth of a fungus. Those bacterial organisms which tend to spread rapidly over the medium produce the greater effects in inhibiting growth. Most bacteria apparently have little effect upon the development of the fungus colony. A limited number, however, are capable of preventing the growth of most fungi.

SOME OBSERVATIONS ON *PINUS VIRGINIANA* MILL. IN MONROE COUNTY, INDIANA: AN ECOLOGICAL STUDY

J. E. Potzger, Indiana University

The writer first became interested in *Pinus virginiana* Mill while on a geology trip through the picturesque Knobstone region of southern Indiana. Beginning near Borden, Indiana, this pine had taken possession of nearly all the slopes and uplands, and had invaded abandoned fields, pastures, and roadsides. At that time it was the intention to make a study of this locality during the summer of 1931, and the plan was suggested to the Central States Forest Experiment Staion. Mr. E. F. McCarthy, at that time director of the Experiment Station, encouraged such an ecological investigation.

Later in the autumn Professor C. A. Malott of the Indiana University Geology Department drew my attention to a grove of pine located about four miles northwest of Ellettsville in Monroe County. A visit to the place proved the grove to be a *Pinus virginiana* consocies similar to the one at Borden, Indiana, only more limited in extent, and it was at once decided to study this area as an initial work on *Pinus virginiana* in Indiana. During the spring of 1931, Dr. E. R. Cumings of the Geology Department called my attention to a similar grove about two and one-half miles west of Bloomington, along Weimer's Lake, and the area was included as part of the present study.

Physiographic Features of the Ellettsville Region. The whole region near the Ellettsville grove is one of singular beauty and scenic attraction. High ridges and hills slope gently into broad valleys. The difference in elevation is mellowed by these long sweeping slopes and rounded crests of the uplands. There is an occasional hint of Karst topography as one meets a sink, and although some of Indiana's highest elevations are close to the area, the absence of rugged declivities softens the feeling of upland topography. The climax is reached as one approaches the crest of the upland on which the pine groves are situated. The hills melt into a wide stretch of level land where farm borders farm, and the upland is crowded into the distant background. This is the famous Flatwoods Region of Monroe and Owen counties. In 1914, Professor C. A. Malott (3) published a detailed work on the region. He says, "Lying between Ellettsville, Monroe County, and Spencer, Owen County, Indiana, is a strip of territory some six miles long and averaging about two miles wide which has been the object of considerable curiosity and study. It is a low level basin nearly surrounded by higher land, yet having several openings in the surrounding periphery of the hills. The surface of the region is mainly ash-colored soil of a fine texture, containing very little sand. It is in reality a

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silt region at the surface, and its outline is clearly discernible at the margin of the basin . . . frequently a hill-like peninsula protrudes out into the region, rising high above the ash-colored silt margin . . . This region of the Flatwoods area is also exceptional in regard to the periphery . . . the hills surrounding the area rise rather suddenly above the basin."

It is on one of these peninsula-like hills, beginning at the foot and extending about one-third up the slope that the area occupied by *Pinus virginiana* is situated. Its exact location is Section 6, T. 9, N. R. 2 W. While the highest ridges of the region are capped by the Chester sandstone, the underlying rock where the study was made is the St. Genevieve limestone, its outcrops are seen at several places in the upper part of the grove, and part of the drainage of this same grove is underground through a small sink in the side of the hill. The soil is of the usual Monroe County residual type, i.e., clay, in the wooded area more or less covered by humus.

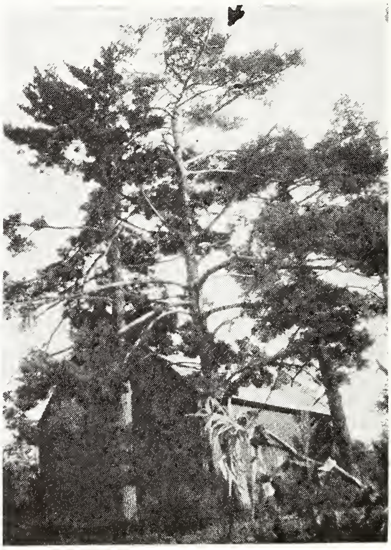


Fig. 1—Parent tree of groves "A" and "B".

The Pennington grove near Weimer Lake is about two and one-half miles west of Bloomington, in the midst of the famous Karst region of the Mitchell Plain, the bedrock being the Salem limestone.

History and Description of the Areas Studied. The grove near Ellettsville where most of the present observations were made is located about four miles northwest of Ellettsville on the side of a high hill which slopes gently down into the Flatwoods Region. The groves are separated by a narrow country road. The upper grove is the property of Mr. Clyde Christie (referred to as Grove "A"), the lower one belongs to Mr. Charles D. Freeman (designated as Grove "B"). The problem was doubly interesting because the owners of the land had seen the trees grow from seedlings to the present mature stage. According to their report, the grandmother of Mrs. Freeman had come to this region from North Carolina about 75 yeas ago and had planted several small white pine and one *Pinus virginiana* near the old homestead. In the course of years the home was moved to the opposite side of the road and a barn was erected on the old cabin site. The barn still stands and over it tower the pines the old pioneer had planted (See Figure 1).

In the immediate vicinity of the barn is a cultivated field, but about 200 meters to the northeast were two apple orchards separated by the before-mentioned road. It was in these orchards that *Pinus virginiana* first became established some 40 years ago. As the trees grew to maturity their seeds added to the extension of the consocies to the east. The area directly adjacent to the orchard where Grove "A" is now located was at that time under cultivation, but was later abandoned and *Pinus virginiana* at once established itself there. About 100 meters to the northwest of the parent tree is a knoll which was left as waste land and the Jersey pine at once took possession of it. No doubt this grove would have extended its limits too if the owner had not cut the trees about twenty years ago.

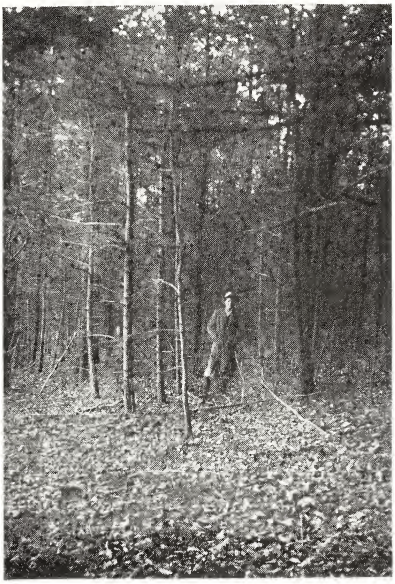


Fig. 2—The dense stand of pine in Grove "B".

After approximately 40 years of establishment and growth, the pine fairly well controls the area of Grove "A" and completely in Grove "B". Figure 2. The crowns form a dense canopy which makes a semi-darkness beneath the trees even on sunny days. Nearly all ground plants are eliminated (See Table I) only the most shade-resisting, i. e. *Galium* *concinnum,* species of Poa, and seedlings of such low trees as *Cornus florida,* and *Sassafras variifolium* persist. In the older part of the groves the needles form a dense ground mat. Eastward of Grove "A" is a pasture and of Grove "B" a cultivated field.

The grove near Weimer Lake was studied in a more comparative way with the Freeman-Christie groves where the main observations were carried on. The place was originally owned by Mrs. Sarah Cree. She and her husband had come to Monroe County from Pennsylvania about 85 years ago. In 1885 her son, Wm. Cree, moved here from Ohio. He does not know how or from where the original tree came to the homestead, but does know that three large trees were growing near the house. One of these trees still remains near the old home-site on the ridge. (Figure 3.) About the time when he came to his mother's home the first successful seedings from the parent tree began on the slope to the south of the trees. At the present time the grove occupies about fifteen acres, and has migrated at least a quarter of a mile to the opposite ridge across an intermittent stream. The character of the grove, the age of the trees, as well as the physical characteristics of the trees are all about identical with those of the Christie-Freeman groves. At present the woods near Weimer Lake is owned by Mr. C. J. Pennington of Bloomington.

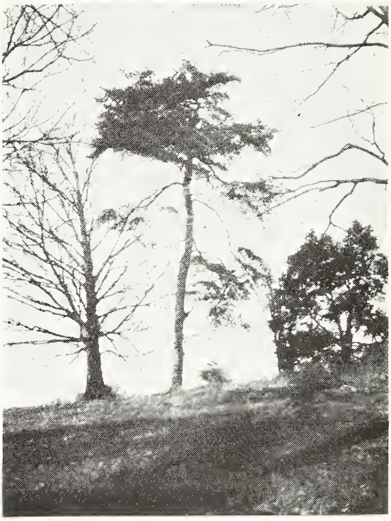


Fig. 3—Parent tree of the Pennington grove.

Some Notes on the Jersey Pine

Regional Distribution. *Pinus virginiana* occupies a unique position in sylvan formation. Livingston and Shreve (5) selected it as a representative type of unusual distribution, and say the following, "*Pinus virginiana* has been used as an example of a type of distribution which is somewhat unusual among the evergreen needle-leaved trees, occupying an area between the northern and southern areas of evergreen needle-leaved forest, and lying almost wholly in the deciduous region."

Its original range was approximately between 34 and 41 N. latitude, and 75 and 88 W. longitude, or from New York southwest to the southern part of Indiana, south to Tennessee, Louisiana, Alabama and Georgia. As far as Indiana is concerned Deam (1) has the following to say, "The distribution in Indiana is quite limited and has never been understood by the authors who variously give it as found throughout the southern part of Indiana. It is confined to the Knob area of Floyd, Clark, and Scott counties, and the southeastern part of Washington County. In the original forests it is confined to the tops of the Knobs where it is associated with *Quercus prinus*. It propagates easily from self-sown seed, hence is soon found on the lower slopes of the cut-over lands and soon occupies fallow fields. It is now found in the open woods several miles east of the Knobs in the preceding counties, but pioneers of this section say it was not a constituent of the original forests but has come in since the original forests were heavily cut over."

TABLE I

Species Represented in the Ground Cover on 50 Quadrats of One Meter Square. Shaded Area of Grove "B"

Species	Frequency index on 50 quadrats
Antennaria sp., Ambrosia artemisiifolia, Galium concinnum, Mitchella repens, Panicum capillare, Panicum sp., Pinus virginiana, Prunus serotina, Quercus alba, Smilacina racemosa.	1
Acalypha ostryaefolia, Carex sp., Cercis canadensis, Fragaria virginiana, Rhus toxicodendron, Tecoma radicans...........	2
Cornus florida, Fraxinus americana, Ulmus fulva...............	3
Isanthus brachiatus, Moss sp.,................................	4
Poa sp..	5
Sassafras variifolium......................................	10

In late years this pine has spread to some extent over much of southern Indiana, so much so, indeed, that it has attracted attention by its rapid and wide-spread invasion and ecesis in new localities. Usually the whole consocies can be traced to one or a few parent trees which had been planted in a farmyard.

Characteristics of the Tree. If one would understand the behavior of a plant it is necessary to study its strong points and its weaknesses, these are the laws through which Nature controls, and Nature's laws are finely balanced. One is first of all impressed with the virility of the pine consocies at these places, and with its present dominance, but at the same time one cannot but be just as forcefully impressed with its physical weakness which will in time eliminate the Jersey pine from the region if human interference does not divert the course of Nature. *Pinus virginiana* is a mesophanerophyte with evergreen leaves reaching a trunk-height of approximately 50 to 65 feet; it is extremely intolerant to shade, seemingly even as seedling, differing in this respect from *Pinus strobus* and *P. resinosa.* The extensive shade-killing is at once evident and striking. Of the trees in dense stands all branches below the top-most crown are dead, so are all smaller trees. Numerous young trees of approximately 25 feet in height were dead. To be exact, in Grove "A" in 1,260 sq. m. there were 35, in Grove "B" 67 in 1,350 sq. m. One will see old trees, evidently pioneers among the invaders, covered with dead branches to within a few feet of the crown. The characteristic of intolerance to shade will be considered more fully in the discussion of the quadrat study. In open places the pine is branched almost to the ground with hardly a dead branch to be noticed. The tree grows rapidly, reaching a diameter of 18 to 20 inches at d. b. h. in 30 to 40 years. Mr. C. J. Pennington has some eight-year old trees near his home which now measure approximately 15 feet in height.

Sargent (4) says, "It is a tree usually 30 to 40 feet high, with a short trunk rarely more than 18 inches in diameter, long horizontal or pendulous branches in remote whorls forming a broad open often flat-topped pyramid . . . its wood is often used for fuel and occasionally manufactured into lumber. It is usually small in the Atlantic states and only on light sandy soil, spreading rapidly over exhausted fields; attaining its largest size west of the Allegheny mountains on the low hills of southern Indiana." Sargent's description of size is not quite in conformity with the size of the older trees in the present study, for there are some trees which reach a height of nearly 65 feet. It does not seem to be choicy as to soil conditions. Some of the trees grow in places where bedrock is close to the surface, on barren soil, showing a decided preference for eroded wornout clay hills, or in fertile soil. Once cut, the stumps decay very readily.

The leaf is very variable in size, ranging from two to three and one-half inches in length, and from straight to a curled form. While the common leaf grouping is two to a fascicle some trees frequently show a three-to-a-fascicle grouping. The cones develop most prolifically on exposed branches, they begin to open early in November. The cone scales are extremely hygroscopic which causes the opened scales to clamp shut rapidly after wetting and to open just as rapidly when dried in wind and sunshine. Seed production is prolific, at least three-fourths of the cone bears well-developed seeds, and as many as 75 seeds to a cone were counted.

General Discussion of the Methods of Study. The problem was attacked from several angles. First of all the old time-tried observational method was employed; information was obtained from the owners of the land who had seen the grove develop.

Soil moisture was recorded from three stations in the Freeman-Christie groves. Station "S" was located in a dense grove of young trees about fifteen years of age as well as in a comparative area just outside of the grove in an open place. The station was on top of the ridge in grove "A". Station "T" was to the eastward of station "S" in the same grove, near the eastern limits of the area. One set of soil samples was taken from an area where the sassafras had been cut and left an open place just beyond the shade of an old pine. Seedlings and four- to five-year old trees were abundant, the comparative part of the same station was about twenty feet eastward under the shade of the parent tree where few seedlings were found. Station "R" was located in grove "B". It was divided into two divisions. One set of samples was taken from the upper limits of the grove and the second set from the lower limits of the same grove, both, however, under the dense shade of pine. Soil samples were taken at one, three and twelve-inch depths. The work was carried on from May to October.

Evaporation observations were made at stations "S" and "T" with the Livingston clay atmometers. The period of observation was also from May to October.

TABLE II

Strip transect through *Grove "A"*. 10 x 128 meters
Tabulation of trees one inch or more in diameter D. B. H.

Species	D.B.H. in inches																	Density	Basal area sq. ft.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	21		
Acer saccharum	4	1	5	2		2					1							15	1.517
Amelanchier canadensis	1																	1	.006
Asimina triloba	2																	2	.012
Carya cordiformis		1																1	.022
Cornus florida		1	2			1												4	.316
Crataegus sp.		9	1															10	.247
Fraxinus americana	3	7	1	1	1	2												15	.836
Juniperus virginiana	8	1	3	1														13	.304
Liriodendron tulipifera								1								1		2	1.745
Malus malus				1														1	.087
Pinus virginiana	30	37	34	20	7	12	19	3	5	6	4	4	5	4	3	1	1	195	41.868
Prunus serotina	1	1															1	3	2.549
Pinus strobus											1							1	.660
Quercus palustris							1											1	.267
Quercus rubra	1	1																2	.028
Sassafras variifolium	74	7		1						1								83	1.230
Tecoma radicans	12	3																15	.138
Ulmus fulva	4	2	2	4														12	.514
Vitis sp	24	3	1															28	.259
Cercis canadensis												1						1	.785

Soil acidity tests were made on soil from representative areas of the groves, comparing, especially, soil where seedlings were dense with soil where seedlings were lacking. The samples of soil were collected in small glass vials. Computation of the acidity was made with the Youdon Hydrogen Ion Concentration Apparatus. Correlation was made between similar areas where the pine had established itself. The groves were studied by the strip transect method. Two areas of prolific seedling reproduction were mapped (one of these in the Pennington grove). The ground cover was listed in 50 quadrats scattered throughout grove "B". Tree study was conducted as follows: In grove "A" the woody plants were studied by the strip transect method. One strip 10 x 128 meters was taken through the center of the grove from the north to the south, and a second strip 10 x 70 meters from the west to the east, about to the center of the grove. (Tables II and III.) A special list of trees according to d. b. h. from one inch up was made in all the areas studied, and a second count was taken of all woody plants one meter

TABLE III

Strip transect through *Grove "A"*. 10 x 128 meters. Area identical with the one on which tabulation of Table II is based. Density of woody plants one meter or higher, less than one inch D. B. H.

Species	Density: Total number of stems present
Acer saccharum	26
Amelanchier canadensis	4
Asinina triloba	33
Celastrus scandens	31
Cercis canadensis	7
Carya laciniata	1
Carya cordiformis	1
Cornus florida	16
Crataegus sp.	2
Fraxinus americana	33
Juniperus virginiana	17
Liriodendron tulipifera	4
Malus malus	1
Morus rubra	7
Nyssa sylvatica	1
Pinus virginiana	51
Pinus virginiana. dead in area	35
Prunus serotina	13
Quercus alba	3
Quercus rubra	1
Rosa sp.	4
Sassafras variifolium	203
Tecoma radicans	61
Ulmus fulva	23
Vitis sp.	12

or over in height but less than one inch in diameter. Besides that a tabulation was made of all dead pine in the areas studied. (Table III.)

The areas were laid off with a heavy cord, measurement being made with a tape line, adjustments were made every ten to fifteen meters for the running of the second line, parallel to the first, so that the measurement was quite accurate. A representative small area 8 x 8 meters was mapped accurately to show position of large trees with reference to

TABLE IV

Strip transect through *Grove "B"*. 10 x 128 meters
Tabulation of trees one inch or more in diameter

Species	D.B.H. in inches																Density	Basal area sq. ft.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Acer saccharum	6	..	..	2	..	1	..	..	..	..	..	..	..	..	..	..	9	.406
Cornus florida	2	6	9	1	..	..	..	..	..	..	..	..	..	..	..	..	18	.672
Crataegus sp.	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	2	.012
Cercis canadensis	9	5	..	2	1	1	..	..	..	..	..	..	..	..	..	..	18	.670
Fraxinus americana	43	7	7	2	1	3	3	1	1	..	..	..	..	..	..	..	68	3 245
Juniperus virginiana	18	8	8	4	..	..	..	..	..	..	..	..	..	..	..	..	38	1.024
Liriodendron tulipifera	..	..	..	..	..	..	..	..	..	..	..	1	..	..	..	1	2	2.181
Pinus virginiana	6	18	26	21	21	24	24	16	17	6	1	4	2	1	3	1	**191**	45.659
Prunus serotina	5	1	1	..	..	..	..	1	..	..	..	..	..	..	..	..	8	.450
Quercus rubra	.	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	022
Sassafras variifolium	6	8	4	5	1	..	..	..	..	..	..	..	..	..	..	..	24	.979
Rhus toxicodendron	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	1	.006
Ulmus fulva	..	3	1	..	..	..	..	..	..	..	..	..	..	..	..	..	4	.115
Vitis sp.	8	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	11	.114

TABLE V

Strip transect through *Grove "B"*. 10 x 186 meters. Area identical with the one where tabulation for Table IV was made. Woody plants one meter or more in height but less than one inch D. B. H.

Species	Density: Total number of stems present
Acer saccharum	5
Asimina triloba	4
Cercis canadensis	6
Cornus florida	9
Celastrus scandens	2
Fraxinus americana	**102**
Juniperus virginiana	19
Nyssa sylvatica	4
Pinus virginiana	**1**
Pinus virginiana dead in area	67
Prunus serotina	3
Rosa sp.	1
Sassafras variifolium	5
Ulmus fulva	7
Vitis sp.	8

the seedlings of *Pinus virginiana.* (Figure 4.) This area has been retained as a permanent quadrat.

In grove "B" a transect was made through the entire length of the grove from east to west, 10 x 135 meters, and a similar strop 10 x 51 meters was run along the eastern border from the north to the south. Tabulation was identical with that described under grove "A" (Tables IV-V). In this area a list of species representing the ground cover was made in 50 quadrats of one meter square, scattered throughout the grove. (Table I.) Along the southern edge of the grove a special study was made of *Pinus virginiana* and *Juniperus virginiana* seedlings. Fifty quadrats of one meter square, alternating with one meter skip were taken. These transects represent about 10 per cent of the total area of grove "A" and 20 per cent of grove "B". The climatological data were taken from the weather report of the Bloomington station. As the areas studied are all within a radius of ten miles from Bloomington, and more or less in the same altitude, these data should be very reliable.

FACTORS HAVING BEARING UPON REPRODUCTION AND GROWTH OF PINUS VIRGINIANA

Let us first consider three factors which might have a decided influence on seedling establishment, i. e., light, soil moisture and soil acidity. Former discussions brought out the fact that light is seemingly a vital factor in the life of this pine. Since few seedlings are found under the old trees (see Table 1) and on the other hand appear in great abundance where older trees have been removed or where older trees are exposed to part of the sunlight during the day, as well as in open fields, along roadsides, and in pastures, one may well conclude that the seedlings must have light to establish themselves, and perhaps even that the seeds need light for germination as do those of *Tsuga canadensis.* The quadrat study of the ground cover (Table I) revealed an almost total absence of seedlings of the dominant species. Only one seedling was found in the 50 quadrats in grove "B", and seeding must be abundant in the old grove. The same absence of young trees is accentuated in the tabulation of trees below one inch in diameter in the four strips studied. Only 51 such young pine were found in 1,980 square meters in Grove "A" and one in 1,860 square meters in grove "B". (Tables III and V.) Comparing with these results the quadrat study along the border of the grove we have 99 pine seedlings in 50 square meters. The most graphic story is told by the mapped area of 8 x 8 meters in grove "A". The area is a rather open place in the northwest corner of the grove in the otherwise dense woods, just adjacent to the strip tabulated which showed no young trees of one meter or over in height. Apparently an old tree had been removed from the place, the growth of sassafras had been cut. While four large pines shaded the spot to some extent, the center is unshaded from the vertical light, and there is an open path for both southwest and northeast light. The

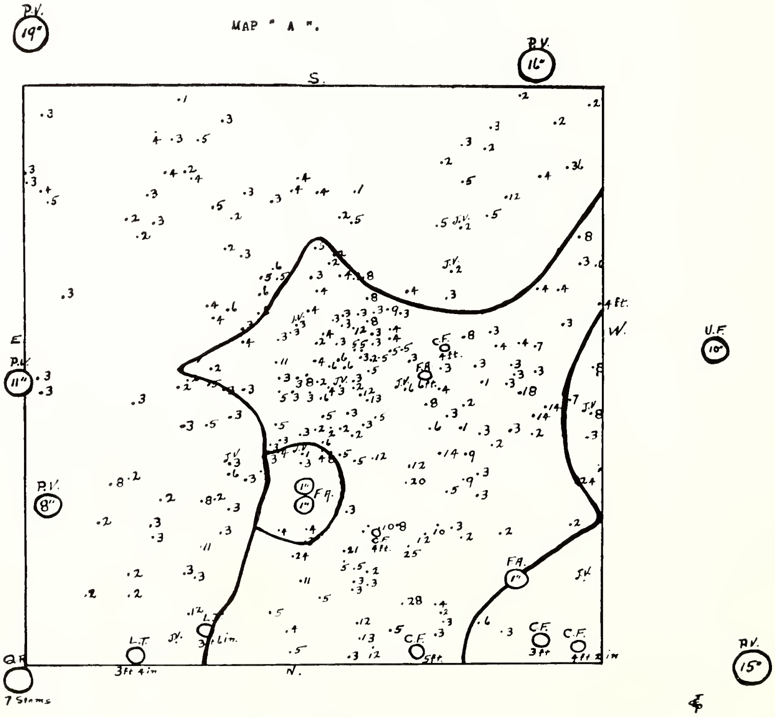


Fig. 4—Distribution of *Pinus virginiana* seedlings in an area 8 x 8 meters. Grove "A".

LEGEND

(C.F.)	Cornus florida
(F.A.)	Fraxinus americana
(J.V.)	Juniperus virginiana
(L.T.)	Liriodendron tulipifera
(P.V.)	Pinus virginiana
(Q.R.)	Quercus rubra
(U.F.)	Ulmus fulva

Dots= Pine seedlings
Figures=Heights in inches
Curved Lines=Shading, vertical
Figures in Circles=d.b.h. in inches

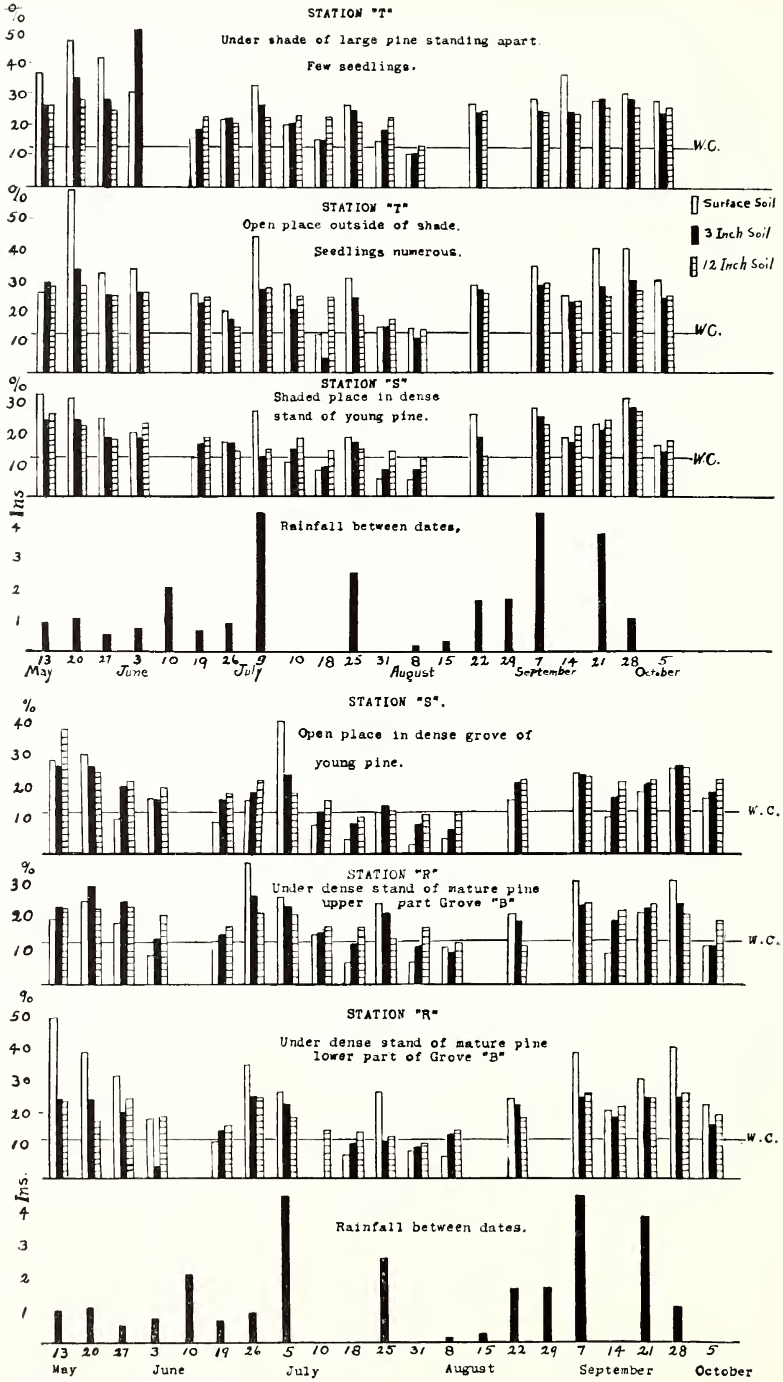
distribution of seedlings is extremely dense in the little plot (251 seedlings), but the most striking thing is that these seedlings are clustered in the central part where the light is unobstructed and in the path of the northeast and southwest exposure to sunlight. The response to the light factor is so immediate that one can almost trace the rim of the shade by the reduction of numbers of pine seedlings. (Figure 4.) The seedlings have invaded the roadside, ditches, fence corners and even quite extensively the pasture, in spite of the grazing interference. On the upper border of grove "A" they have taken possession of an abandoned strip of land grown over with herbaceous plants and some *Rubus allegheniensis.* Mr. Freeman said that hundreds of the seedlings would invade the area east of grove "B" whenever it was left in grass for a few years.

Let us turn our attention to the question of soil acidity. Since seedling establishment would be most influenced by the condition of the surface soil, investigation on acidity was limited to this layer. Soil was taken from areas which were close to the parent trees so that the question of seeding is comparable. It is rather striking that the surface soil under the old pine shows so little acidity since the leaves of conifers are acid in their reaction. The samples of group "A" were taken from beneath the older pine trees, the pH was as follows: 6.89, 6.81, 6.43, 6.57, 7.15, 7.73. There is, thus, a range of acidity in pH between 6.43 and 7.73.

The samples of group "B" were taken from beneath deciduous trees. The distribution of the acidity in pH is as follows: 6.40, 6.81, 7.35, 7.40, 7.42, 7.44, 7.5, 7.56, 7.58, 7.73, 7.9. While the difference in acidity between the various soil samples shows a considerable range, the difference between the two groups is not great. If seedling growth were promoted by slight variation in acidity or alkalinity of soil, one should expect to find seedlings in one of these two areas which are comparable as to seeding but diverge slightly as to range of acidity. In neither of these areas was there a noteworthy seedling growth. There is not even a definite indication of preference for acid or alkaline soil in places where the seedlings are numerous as shown by the samples of group "C," which showed the following range: 6.44, 6.49, 6.72, 7.0, 7.06, 7.12, 7.23, 7.23, 7.73, 7.85, 7.92. There is approximately the same range in pH as in the previous groups. One might argue that soil acidity is subject to local fluctuations due to the influence of grass or herbaceous plants and that seedlings might thus show a selective preference for certain soils. We admit such a possibility, but the soil under pine and deciduous trees shows just such a fluctuation and yet seedlings are absent from these areas. From the evidence on hand we must conclude that acidity or alkalinity of soil is not a critical factor in retarding or promoting establishment of seedlings of *Pinus virginiana.*

The results of the soil moisture measurements are rather striking in a number of ways. One is impressed with the many weeks during which soil moisture dropped below the wilting coefficient. It was most frequent in the surface soil and least in the soil at 12-inch depth. (See Figures 5 and 6 and Table VI.)

This lack of soil moisture becomes doubly significant when correlated



Figs. 5 and 6—Soil moisture content for stations "R", "S", and "T" and wilting coefficient for the 12-inch soil.

Lower graph shows rainfall in inches between dates of collection.

TABLE VI

Number of weeks when soil moisture dropped below wilting coefficient during a period of 18 weeks of observation. Abridged from Figures 5 and 6

Station	Location	Surface soil	3-inch	12-inch
R	Upper edge Grove "B"	6	4	2
	Lower	4	4	1
S	Open place	7	3	3
	Dense grove	5	3	1
T	Open place	1	2	0
	Under old tree	1	1	0

with the rainfall for the summer. The summer of 1931 had an abundance of rain in every month of the summer, but with May rising above normal, with July double that of normal, and September more than three times that of the normal. As figures of monthly rainfall do not show the significance of this moisture to the soil, since they cannot indicate the distribution of the rainfall over the period, a special graph has been added to each figure showing the soil moisture for the 21 weeks while the investigation was conducted in order to indicate the distribution of the rainfall week by week. As a whole the rainfall was well distributed; during ten weeks there was at least an inch or more of precipitation. (Figures 5 and 6.)

Under such conditions of precipitation one would expect sufficient soil moisture to keep the amount of water in the soil above the wilting coefficient. The low water content of the soil may be partly attributed to the Karst region, which permits a rapid underground flow-off.

There was a remarkable lack of soil moisture under the shade of dense stands of pine, even the open place at station "S" which was exposed to sunlight almost the entire day was not so very much lower in soil moisture than the areas under dense groves of pine. In fact, the 3-inch level in the exposed area was one week less below the wilting coefficient than those of station "R" lower down the slope under a dense pine grove. Station "T" on a plateau of the lower part of the ridge showed least lack of soil moisture of all stations. One might expect that, since it was less subjected to rapid run-off on account of its topographic position.

It must also be taken into consideration that station "S" was near a sink, so that the greatest lack of water in the soil could be expected there, but station "R" near the foot of the upland registers almost as many weeks below the wilting coefficient and in the 3-inch soil even more.

Here it must be a case of root absorption as has been shown by trenching experiments carried out by Toumey and Kienholz (6). On the other hand one must not look for the entire explanation of this lack of soil moisture in root competition. After years of observations on trenched areas, the last-named authors make the following statement: "We are coming to believe that the nature and conditions of the reproduction and other surface vegetation beneath living canopies are not due to any single factor such as light or soil moisture, but to a complex of factors."

The soil moisture condition is also greatly influenced by the interception of rainfall by the crowns of the trees. Zon (7) says: "As a result of a great number of investigations it may be assumed that coniferous forests intercept more precipitation than broad leaf forest." Ney found that pine forest intercept fully 20 per cent of the precipitation, while beech forest but 9 to 15 per cent. (See Zon, loc. cit., page 26.)

Considering the factors which seem to prevent seedling establishment, one must conclude that root competition, interception of rainfall

MAP "B".

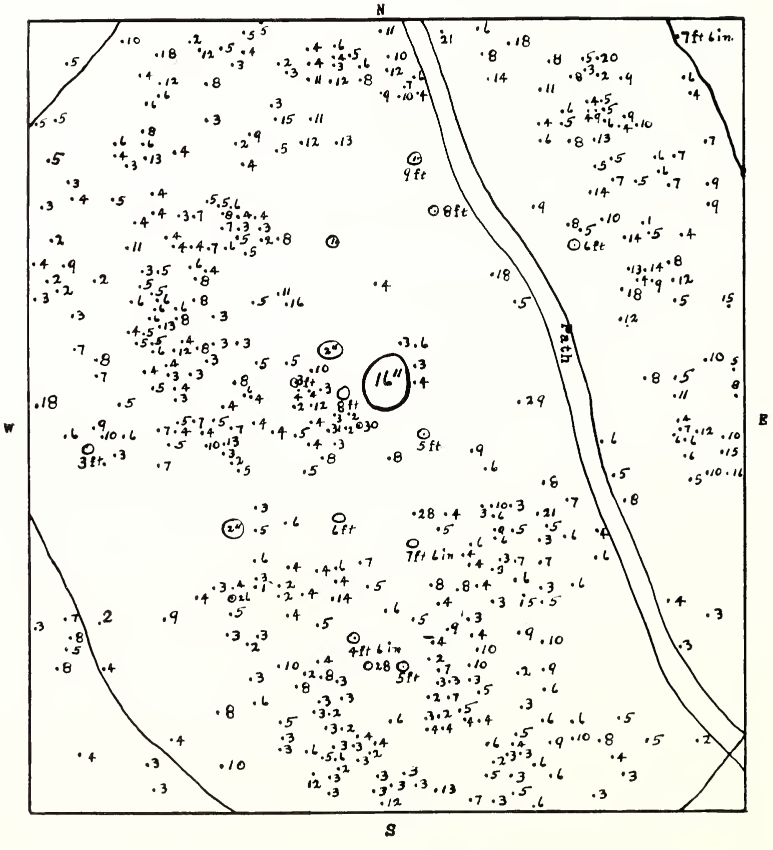


Fig. 8—An area 9 x 10 meters under a mature pine in the Pennington grove. Lines in the corners mark extent of branch-spread. Each dot represents a seedling, figures indicate size in inches.

by the tree crowns, and shading are the most prominent in the case of *Pinus virginiana*. From the general appearance of things, the writer is inclined to consider intolerance to shade the most vital of all. Not only is the absence of seedlings under the dense stand of older trees a striking feature in all the groves investigated, but likewise the killing of young trees up to two inches in diameter where the crowns do not reach above the canopy and the killing of all shaded branches of the older trees. When a tree grows in the open it retains its branches alive to the very lowermost branch. In the Pennington grove are several large areas within the dense stand of old trees which are not occupied by big pine and to all appearance should have a reduced root competition, but the crowns cause shading for the greater part of the day. No seedlings have come in. Nearby is a similar area partially encircled by *Cornus florida and Liriodendron tulipifera*, leaving, however, an open path to the morning sun and a thrifty growth of young pine occupies the area. Likewise seedlings were found in profusion under older trees which occupied an isolated open position. The most outstanding case of this nature was mapped and is shown in Figure 8. The old tree occupies an isolated position towards the top of the slope, the east, southeast, north, and northwest sides are flanked by open fields, while a grove of 22 young trees about 18 years of age is to the west; few seedlings are found in the grove; about eight meters to the south is the dense main forest with almost a total absence of seedlings and young trees.

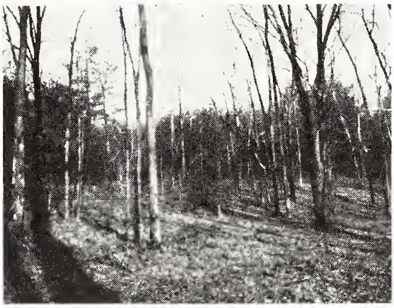


Fig. 7—The sharp demarkation of pine between upland and lowland in the Pennington grove.

Root competition must certainly be intense under the parent tree, yet the parent tree is not only void of dead branches but there is also an amazing number of young trees ranging from two inches to nine feet within the boundary of its branch-spread; 455 seedlings and small trees in a limited area of 9 x 10 meters. Many of these seedlings grow in dense mats of Poa, and also among *Rubus allegheniensis*, even near a path which crosses the area. These are all conditions which certainly point to a severe root competition or its equivalent with which the young growth must compete and does compete successfully. Pearson (3a) found that in some instances light was a more important factor in inhibiting seedling establishment than soil moisture in forests of the Southwest, and cites cases identical with those given by the writer.

In order to study more definitely the role which root competition plays in the elimination of seedlings under dense stands of older trees, the writer has planned a trenching-experiment. Mr. C. J. Pennington has most kindly granted permission for such an experiment in his woods.

The fact that the Jersey pine readily takes possession of dry wornout hillsides and does not invade the more moist lowlands also argues against the soil moisture factor as an extreme controlling influence on the establishment of seedlings under parent trees. In the Pennington grove one finds a sharp line between dense growth of pine on the dry uplands and the total absence along an intermittent little creek in the valley, unoccupied areas are numerous. (See Figure 7.)

Another unusual feature in the present soil moisture studies is the close range of the wilting coefficients in all three layers of soil, and at all three stations. In collecting the soil a hole about 14 inches deep was dug with a spade and the soil samples taken from the wall of the opening at the depths from which measurements were to be made. The soil was collected in two and one-half by three-quarter inch cans with a tight-fitting lid on which the weight of the can, the station, and the depth of soil were written with ink. These cans were usually weighed on the day of soil collection, then with lids removed placed into an electric drier during at least four days at 103 C. At the end of the drying the cans were closed one by one as they were removed from the oven and weighed immediately for the computation of water loss.

In the figure showing the soil moisture data, the wilting coefficient is that for the 12-inch soil. The distribution of the w. c. for the various stations and soil depths were as follows:

TABLE VII

The wilting coefficient for the various stations

Stations and Designated Area	Surface	3-inch	12-inch
Station "R"—			
Upper part of grove..................	11.7	12.4	12.7
Lower part of grove..................	12.8	11.8	12.3
Station "S"—			
Dense grove of pine..................	11.1	11.8	12.6
Open place near pine..................	11.7	11.1	12.5
Station "T"—			
Outside of shade of old tree.........	13.5	12.1	12.9
Under shade of tree..................	12.9	12.8	13.0

Evidently there must be a more or less complete oxidation of the decaying plant remains on the surface soil. Pine leaves also yield a much more scant amount of leaf-remains than broad leaf trees, and these factors combined will make the layers of soil at different depths more uniform than is the case in forest of deciduous trees.

As already stated, the areas studied are at present dominated by *Pinus virginiana*. This will also be borne out by the figures of the strip transect studies which have been tabulated in Tables II and IV.

Compacting these figures still more, we have a grand total as shown in Table VIII.

TABLE VIII

The number of individuals of *Pinus virginiana* in area

Grove	Area tabulated	Trees having diameter of 1 to 21 inches D. B. H.	Below 1 inch D. B. H.
A	1,980 sq. meters	205	51
B	1,860 sq. meters	193	1

The whole area shows a marked absence of competitors in large-leaved trees, there are really only two species which show any amount of representation, i. e., *Acer saccharum* and *Fraxinus americana,* neither of them comparable in numbers with *Pinus virginiana.* A further study of the size of the trees as shown in Tables II and IV reveals the fact that nearly all the large trees are pine. A compact tabulation of size distribution of *Pinus virginiana* in the tabulated areas is shown in Table IX.

TABLE IX

The distribution as to size of *Pinus virginiana* in mapped areas

Grove	Measurement D. B. H. in inches																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	21
A	30	37	34	20	16	12	19	3	5	6	4	4	5	5	3	1	...	1
B	6	18	26	20	21	24	24	16	17	6	1	4	2	1	3	3	1	...

The situation becomes different when examining Tables III and V, showing the distribution of trees below one inch in diameter, the aspect of the area pointing into the future. Of this more will be said under the topic of predictions.

Ever and again one is impressed with the importance of shading in the elimination of reproduction of *P. virginiana.* Even the climatological data show this importance. Monroe County is well within the deciduous forest area of North America, which means that its climatic conditions are such as to make dense forests and wide range of deciduous trees possible. Also the individual species are represented in large numbers within a forest, this makes for increased competition. The average rainfall for the Bloomington area is approximately 44 inches a year, and while there might be a fluctuation from the normal monthly and yearly amount, over a period of years these differences tend to smoothen out along the normal curve. Figure 9 shows the normal rainfall in inches and its monthly distribution for the Bloomington area.

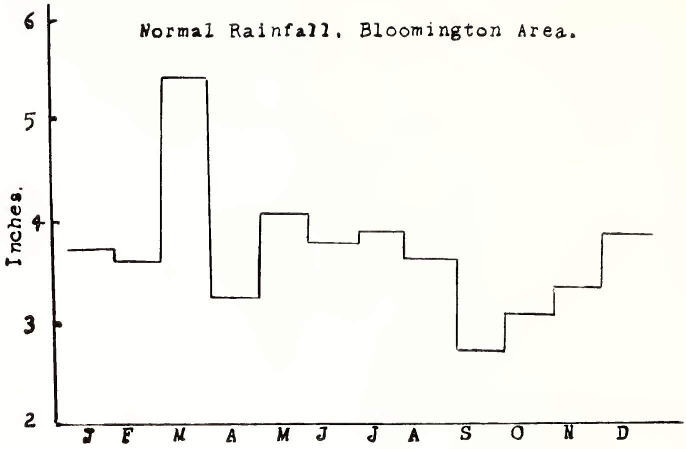


Fig. 9

In its regional distribution the Jersey pine follows quite closely the areas between the 40 and 50 inch isohyet lines, so the Bloomington area precipitation seems to be just the ideal for its moisture requirement. From the description of Sargent (4) one can well deduct that it can readily adapt itself to less favorable moisture conditions brought about by physiographic features of the locality than many of the deciduous trees, for it takes possession of the sandy soil in the East and spreads readily over slopes of uplands where moisture conditions are more severe than in the lowlands due to greater run-off and increased evaporation brought about by exposure to increased air currents. This habit of invading less favorable areas, again, points to the same weakness of intolerance to shading. While it can adapt itself to the drier uplands many of the broad-leaved competitors cannot and are so eliminated, which means a partial protection from shading by larger trees. The readiness with which it invades drier uplands would make it a desirable tree for reforesting idle and eroding uplands of central and southern Indiana. Even the seedlings tend to prove that this pine can endure unfavorable soil moisture conditions, for although the year 1930 was one of great drought which affected full-grown trees on the uplands and killed 84 per cent of a series of hemlock seedlings in Brown County, Indiana, which were under the observation of Professor Ray C. Friesner and the writer, the mapped areas in grove "A" and the Pennington grove as well as the quadrat study along the southern border of grove "B" indicated no great losses during that year for many of the seedlings were of that year's germination.

Evaporation is somewhat linked up with the relative humidity of the air so that evaporation increases with the increase of the air temperature. However, the influence of isolation upon evaporation is only a part of the story, especially when local limited areas are concerned, for moisture may also be transferred by air currents. This movement of water vapor by air currents is indicated by the present evaporation studies.

TABLE X

Standard evaporation for nineteen readings. Averaged weekly

Station	Set	Location	Weeks and amount of evaporation in cc.																		
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
S	1	Dense grove....	137.6	92.4	60	....	.....	36.0	37.0	....	.....	46.4	144.7	105.7	88.0	88.0	32.9	92.8	71.2	52.8	100.8
S	2	Open place.....	126.4	108.2	88.5	83.7	98.3	55.3	47.3	93.9	152.1	92.4	164.0	123.7	105.0	105.0	74.6	97.9	77.4	....	109.0
T	3	Outside of shade of old tree....	135.4	116.2	101.4	82.1	96.9	42.9	54.1	72.5	115.9	44.4	109.0	81.6	66.6	66.6	....	111.0	76.2	51.1	97.7
T	4	Under the shade of old tree....	142.1	124.3	109.5	99.9	136.9	51.8	43.6	96.6	134.1	48.1	130.7	102.3	100.6	100.6	47.0	119.1	86.6	68.1	102.9

The atmometers for results of sets one and four of Table X were in a shaded area yet the amount of evaporation is in some instances higher than of those in the open sunlight. It is especially pronounced in set four when compared with set three. Only during one week was there more evaporation in the open than in the shade of the large pine where the atmometer for set three results was located. This can only be explained on the basis that the atmometer was in a less protected position as far as air currents were concerned.

As a whole, the evaporation was low for the whole season and this makes the lack of soil moisture so much more difficult to explain. Excessive flow-off on the steep slopes, porous bed-rock account for a part of it, the balance must have been evaporated through the tree crown. After all, evaporation figures from studies of these processes near the surface convey only a partial idea to what extent plants of the ground cover are affected by evaporation, for the taller trees are subjected to an evaporation at least 75 per cent higher than are the plants protected by the forest. This was shown by King (2) on observations of the influence of wind-breaks on field crops.

The results also show that evaporation data alone do not convey a great deal of information as to the effect water loss has upon plant growth, for evaporation is only one part in a complex of factors involved in the understanding of the relationship between precipitation and soil moisture.

Predictions. To judge by the situation in the observed areas as well as from reports on numerous other places where this pine has given expression to rapid spread, one may expect that within the next 50 years wide areas in southern Indiana will be invaded, for the tree is seen in many places near homes. Waste lands and abandoned fields will be possessed by the rapidly growing conifer. The future may also show some important economic value for the timber. Mr. E. F. McCarthy, formerly of the United States Department of Agriculture, Central States Forest Experiment Station wrote me the following of its economic possibilities: "*Pinus virginiana* will have a certain amount of value as saw timber, especially in farming communities where other more desirable softwood species cannot be secured. It has already been used for pulpwood and in small sizes with an excess of sapwood it may be possible to develop satisfactory sulphite pulp." Since the tree grows very readily on poorer upland soil as well as on rocky hillsides and waste lands in general, it may serve as a forest-crop on lands lying idle at present, and thus put a stop to much wasteful erosion of deforested uplands.

No doubt every life-form has its proverbial Achilles heel, and so has the Jersey pine. Since it is very intolerant to shade, any invasion of the consocies by taller trees will readily eliminate it from an area where it was dominant for a time. Such invasion is also very probable in the Freeman-Christie groves, since seedlings do not develop under the parent trees. In these groves the invader seems to be *Fraxinus americana.* In the tabulated area of grove "A" this species is represented by 15 individuals one inch or more in diameter and 33 of smaller diameter, one meter or more in height. In grove "B" there are 68 above one inch in diameter and 102 of the smaller sizes. Comparing the representation of the small growth of *Pinus virginiana* with these figures we have only 51, so one can readily picture the eventual fate of the conifer in that area. At present all other species, even the common middle layer trees of our deciduous forests, i. e., *Cercis canadensis* and *Cornus florida*, are poorly represented. In the dense stand of grove "B" even sassafras is very scarce. So for the present *Pinus virginiana* dominates in the described areas, as soon as taller shade-resisting trees come in the smaller pine will be eliminated from the area.

Summary

1. *Pinus virginiana* is spreading rapidly in some areas of Monroe County, Indiana, as an escape from isolated trees in cultivation.
2. The preferred places are waste lands, abandoned fields, cut-over woods, especially of the more dry upland types.
3. Its foremost assets in aiding establishment are ready self-seeding in open places, rapid growth in dense consocies, and adaptability to semi-xerophytic conditions.
4. Its greatest weaknesses are small size and extreme intolerance to shade.
5. There is practically no reproduction under the parent trees where the crown is so dense as to greatly reduce sunlight.
6. The lack of seedling establishment under dense growth of parent trees is seemingly the result of lack of light and soil moisture; of the two, lack of light seems to be the greater inhibiting factor.
7. The prolific reproduction in open areas and on worn-out land, as well as its rapid growth would adapt it admirably to projects of reforestation of waste lands and barren hills.

ACKNOWLEDGMENTS

The writer expresses his sincere thanks to all who assisted in locating areas in Monroe County which were occupied by *Pinus virginiana;* to Professor C. A. Malott of Indiana University for checking the physiographic descriptions; to Messrs. C. D. Freeman, Clyde Christie, C. J. Pennington for the cordial permission that experiments might be carried out on their property, and for all valuable information of historic importance; to Professor Ray C. Friesner of Butler University for taking care of the atmometer and soil moisture work while the writer attended the Biological Station of the University of Michigan; to Rexford Daubenmire of Indianapolis for like services; to Mrs. Ray C. Friesner for assistance in compiling the evaporation data; to the Butler University Botany Department for the use of their centrifuge; to Professor Stanley A. Cain of Indiana University for figure 2 and for all helpful suggestions for the improvement of the paper and the presentation of the tables.

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PLANTS PREVIOUSLY UNREPORTED FOR MONROE COUNTY, INDIANA

J. E. POTZGER, Indiana University

The appended list of 32 plants previously unreported for Monroe County, Indiana, have been collected by the writer during the year 1931. A specimen of each is deposited in the herbarium of Indiana University and in the private herbarium of the writer. The nomenclature used is that of Gray's New Manual, seventh edition.

Collected four miles north-west of Ellettsville:

Acer saccharum var. *Rugelii* (Pax) Rehder. Upland woods.

Apocynum cannabinum L. Along a ditch near the road.

Houstonia ciliolata Torr. On a dry hill. Common.

Pinus virginiana Mill. Escape from trees planted near a home. Covering about 8 acres near Ellettsville, and 15 acres two miles west of Bloomington.

Collected in or near Bloomington:

Lepidium campestre (L.) R. Br. Along a railway track.

Salvia lyrata L. Indiana University campus, near Indiana Ave.

Collected in Salt Creek Valley and adjacent uplands:

Acalypha ostryaefolia Riddell. Along the road, top of a ridge.

Amphicarpa Pitcheri T & G. In shady place near a small stream.

Arabis laevigatus (Muhl.) Poir. In shady beech woods of the plain.

Aspidium cristatum (L.) Sw. In shady Sphagnum swamp.

Bartonia virginica (L.) B. S. P. In shady swamp.

Bidens trichosperma (Michx.) Britton. In wet, swampy soil.

Betula nigra L. In low woods. Along bank of Salt Creek.

Cerastium arvense var. *oblongifolium* (Torr.) Hollick & Britton. Along edge of ditch.

Collinsia verna Nutt. Was originally reported by A. N. Barnes in 1881. In shady valley, along a stream.

Desmodium laevigatum (Nutt.) DC. Along edge of woods on dry hill.

Erigenia bulbosa (Michx.) Nutt. In beech woods of the plain.

Fraxinus nigra Marsh. In woods of low ground along Salt Creek.

Habenaria clavellata (Michx.) Spreng. In swamp. Rare.

Helianthus giganteus L. Along country road at foot of ridge. Rare.

Ilex verticillata (L.) Gray. Not reported since Coulter's report of the flora of the state in 1899. Dominant high shrub in the Sphagnum swamp.

Lespedeza striata (Thumb.) H. & A. In abandoned field of the plain.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

Mentha arvensis var. *canadensis* (L.) Briquet. Along stream of shaded valley.

Monarda mollis L. On dry ridge.

Polygala sanguinea L. In old abandoned field near a creek.

Polygonum arifolium L. Along edge of swamp, shady moist woods.

Pycnanthemum virginianum (L.) Durand & Jackson. On dry hillside.

Saxifraga pennsylvanica L. In Sphagnum swamp.

Saururus cernuus L. In low ground along a stream. Shaded densely.

Solidago hirtella (Greene) Bush. Along fences and edges of woods.

Solidago patula Muhl. In swampy places.

Ulmus racemosa Thomas. A tree of the lowland woods.

THE ALGAE OF INDIANA[1]

B. H. SMITH, Indiana State Teachers College

This paper presents a list of algae, with the exception of the diatoms, which have been found in Indiana.

The collections, from which this systematic list was prepared, were made largely by the writer during the past three years, 1928-29, 1929-30, and 1930-31, and represent more than 1,200 collections from 29 counties. The writer is well aware of the fact that this list is perhaps far from complete for the state and that an approximate list must take years of collecting and determining, a task which he hopes to continue. Little or no attempt was made to make determinations in the field as this greatly retarded collecting and under such conditions facilities are not so good for accurate determinations. The material as a rule, that is unless it could be examined in the laboratory shortly, was placed directly in Transeau's Solution which consists of water, 95 per cent alcohol and formaldehyde, in the ratio of 6:3:1.

The writer made approximately 1,000 permanent slides. The material was removed first from the preservative and placed in 10 per cent glycerine and water, using a watch glass. The glycerine was allowed to concentrate by evaporation of the water for two or three days, when pure glycerine was added. The material was now placed on a slide and a small drop of melted glycerine jelly was added (this jelly must not be too warm) and allowed to solidify over night. The slides were then sealed by ringing with balsam. For the desmids this seems to be a very satisfactory method but is very unsatisfactory for the Zygnemales.

Historical. The literature dealing with the algae of Indiana consists of approximately forty papers, many of which do little more than mention one or two genera. The first written account of the algae of the state seems to have been made by Cox (1876) who lists the genera Oscillatoria and Closterium, and *Pediastrum angulosum* (Ehrenb.) Menegh., *Euastrum ansatum* Ralfs. and twelve genera of diatoms without species names. These were all from Wayne County. The second report on the algae was by Curtis (1882) who reported approximately seventy-eight diatoms from Marion County. Johnson (1891) lists several species mostly from Lake County, in the northwestern corner of the state. Mottier (1894) adds Bloomington as a new station for Pleodorina. Eigenmann (1895) mentions Ceratium hirundinella O. F. M. diatoms or other minute organisms along with various forms of Palmella in the first report of the biological station which is located on Winona Lake, in Kosciusko County. Arthur (1896) lists *Cladophora glomerata genuina*

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[1] This paper is part of a thesis presented in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Graduate School of the Ohio State University.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

Kirch. and Chamaesiphon. Bigney (1896) in his survey of Milan Pond, says the pond is very rich in algae and then proceeds to name such genera as Spirogyra, Zygnema, Vaucheria, Oscillatoria Euglena, diatoms, desmids and kindred forms. Thomas (1898) lists fifteen desmids from Crawfordsville in Montgomery and remarked he was surprised that no more has been done on the algae and made a plea for further work in the field. Burrage (1901) found 14 genera of diatoms and five genera of other algae in the Lafayette Reservoir. By far the largest list of algae was made by Andrews (1909) when he reported about 175 species mostly from Monroe County. Again Andrews (1926) reported an additional list of species of about 88 in number. Palmer (1928 added five new species for the state. Palmer (1931) again reports 13 new species and 3 new genera of algae from Indiana.

Andrews (1929) in a third article lists 52 species including some diatoms, all from Monroe County. Palmer (1930) adds some 22 genera and seven species of algae to his check list for 1875-1928. In the same year he also adds Lemanea as having never been listed for the state. White (1930) lists 22 species of algae as not previously reported for Indiana.

This review of literature shows very clearly the meager amount of work which has been done on the algae in the state since the beginning fifty-five years ago. It is no doubt true that much of the earlier work and perhaps some of the latter work on the algae in this state was done under unfavorable conditions, especially with reference to access to dependable literature. This is perhaps particularly true with reference to the species of Spirogyra, Zygnema, Mougeotia, Debarya and the family Oedogoniaceae. Up to the present time there is no satisfactory published key or monograph of the Zygnemaceae and it was only by the use of the unpublished keys of these genera by Transeau that the writer was able to make satisfactory determinations. In 1925, Transeau published a key with descriptions and drawing of the species of the genus Debarya and in 1926 appeared his key to the genus Mougeotia.

In 1929 Tiffany published his key to the Oedogoniaceae and followed in 1930 with the publication of his monograph of the same, the only complete work in English on this family. Up to this time the work of Hirn (1900) published in Latin and German was the model for all algologists. This work was not only difficult to secure but was becoming obsolete.

In brief this shows the scattered condition of the literature dealing with some of the very common genera of algae, which made accurate determinations difficult.

Summarizing the literature up to the time this paper was presented before the Indiana Academy of Science we find that out of 92 counties in the state, algae have been recorded from but 19 counties and for 8 of these counties there have been less than 10 species reported. Nine counties have more than 10 species reported, they are Marion, Marshall, Montgomery, Lake, Lawrence, Kosciusko, Wayne, Monroe, and Tippecanoe. Summarizing the number of genera and species previously reported in the state we find: Blue-greens—28 genera and 100 species and varieties, one genus had no species named; Desmids—16 genera and 164 species; all others, 63 genera and 217 species and varieties, 9 of these genera have no species named. Omitting the genera with no species named there are 106 genera and 479 species recorded for the state. This does not include the diatoms of which there are 30 genera and 120 species reported, 5 genera having no species named. Curtis (1882) reported 78 species, which shows there has been essentially nothing added to his efforts.

Geographical. Indiana may be divided into three rather general regions: (I) The Northern Lake and Moraine Region, the southern limit of which may be indicated by a line beginning at Ft. Wayne, in Allen County, and passing through Huntington, Peru, Logansport, Monticello and proceeding westward through the lower edge of Jasper and Newton counties, into Illinois. This region might be further subdivided into sections as follows: (1) Calumet Lacustrine, (2) Valparaiso Moraine, (3) Kankakee Lacustrine, (4) Steuben Morainal Lake and (5) Maumee Lacustrine section. This region as a whole is a rather rough plain. Scattered over it are belts of low, hummocky hills, many lakes, and patches of sand hills intermingled with marshes. These belts of sand and gravel were laid down at the margin of ice while the margin was stationary and are frequently called terminal moraines. In Allen County only, on the east, do we find silt and clay in the beds of old extinct lakes, drained thousands of years ago. In north central Indiana are found belts of gravelly clay, mixed by the glacier, which are from 100 to 200 feet thick and also belts of sand, gravel and gravelly clay, mixed in confusion by the glacier, and the surface strewn with hard bowlders. In the northwestern section, Newton, Jasper, Pulaski, Stark, and Laporte are found belts of sand, silt and gravel laid down by the rivers and lakes. Here are found the sand dunes, hillocks and hollows of sand blown by the wind, gravelly clay mixed by the glacier and bowlders again strewn over the surface. (II) The Central Drift Plain, sometimes called the Tipton Till Plain, a region truly a plain, being level and smooth, extending southward from the Northern Lake and Moraine Region to Posey County in the extreme southwestern part of the state and to Clark County on the southeast. The latter county is opposite Louisville, Kentucky. This region extends over the middle and southern two-thirds of the state, except for fifteen counties. Its southern limit corresponds with the southern limit of glaciation. This central drift plain has three distinct divisions or sections. The north central region which covers about one-third of the state is a gravelly clay of 100 to 200 feet in thickness and was mixed by the glacier. The region is sometimes called a ground moraine. The southwestern region and the southeastern region correspond to the limits of glaciation. Here the soil is gravelly clay, as in the north central region, except it averages from 0 to 50 feet thick and is somewhat enriched by loess loam and imperfectly mantles the bed rock. (III) The Southern Hills and Rolling Land, a region found in central southern Indiana, of about 6,250 square miles. This is an exceedingly rough region as compared with either of the other two regions of the state. There are about fifteen counties in the section, beginning with Brown and Monroe counties on the north and extending southward to the Ohio River. Here are the unglaciated hills of valleys and it constitutes the most rugged region of Indiana. The soil is made up largely of bed rock made by the weathering of shale and limestone and some sandstone.

The writer wishes to thank Dr. E. N. Transeau, under whose guidance this work was made possible and accomplished, for his helpful criticisms, the checking of many determinations, especially of the Zygnemaceae, and also for the use of his unpublished keys of the species of Spirogyra and of Zygnema, without which their determination would have been nearly impossible. To Dr. L. H. Tiffany the writer is greatly indebted and many thanks are due for his assistance with the Oedogoniaceae, and to Dr. Helen J. Brown thanks are likewise due for her assistance with the Desmidiaceae. For assistance in the determination of the Peridineae the writer wishes to express his appreciation and thanks to Mr. G. H. Wailes, of the Pacific Biological Station, Nanaimo, British Columbia. He also expressed appreciation to those of his students who helped in making some of the collections: Max Britton, Francis Post, Ben Frandzel, Mary Frances Caress, and Claude French.

SUMMARY

Of the 540 forms in the list there are 101 varieties, 272 species and 30 genera which have not been recorded in published reports from the state.

There are 22 species and varieties not recorded in published literature from the United States. These are as follows:

1. *Oedogonium armigerum* Hirn. Previously reported from Brazil.

2. *Oedogonium biforme* Nordst. Previously reported from Brazil, Paraguay and Ecuador.

3. *Oedogonium crassiusculum* Wittr. var. *arachavaletae* (Wittr.) Hirn. Previously reported from Uruguay.

4. *Oedogonium inconspicuum* Hirn. Previously reported from Colombia; Finland, Austria and Sweden.

5. *Oedogonium paulense* Nordst and Hirn. Previously reported from Brazil and Australia.

6. *Scendesmus quadricauda* var. *africana* Fritsch and Rich. Previously reported from South Africa.

7. *Spirogyra bucheti* Petit. Previously reported from Morocco.

8. *Spirogyra nawaschini* Kasanowsky. Previously reported from Europe.

9. *Spirogyra schmidtii* W. & G. S. West. Koh Chang, Siam.

10. *Spirogyra subreticulata* Fritsch. Previously reported from South Africa.

11. *Spirogyra tolosana* Comere. Previously reported from France.

12. *Spirogyra velata* Nordst. Previously reported in Europe; South Africa.

13. *Cosmarium lundellii* var. *ellipticum* West. Previously reported from Wales and Scotland.

14. *Cosmarium obtusatum* Schmidle. Previously reported from Scotland, Germany, Austria (2) and East Africa.

15. *Ceratium hirundinella* var. *carenthianum* Zederb.

16. *Ceratium hirundinella* var. *pilburgense* Zederb.

17. *Glenodinium oculatum* Stein. Reported from Europe and Australia.

18. *Peridinium elpatiewsky* (Ostenf.) Lemm. Reported from Europe and Asia.

19. *Peridinium lomnicki* Wolsz. Reported from European waters.

20. *Peridinium penardi* Lemm. Reported from plankton of ponds and streams in Europe.

21. *Closterium dianae* Ehrenb. var. *arcuatum* (Breb.) Rabenh.

22. *Vaucheria uncinata* Kuetz. Reported from Norway and Europe.

Eddy (1930) says that 16 of the known species of the fresh water dinoflagellates have been found in the United States. Of these 16 known species the writer has found four in Indiana. In addition to this, six species not reported for the United States and two new species were found, making a total of 12 species and varieties for the state.

The new forms and names are as follows:

1. *Oedogonium borisianum* var. *minus* var. nov. L. H. Tiffany and B. H. Smith.
2. *Oedogonium suecium* var. *australe* (G. S. West) L. H. Tiffany and B. H. Smith.
3. *Vaucheria orthocarpa* (Reinsch) var. *major* var. nov.
4. *Closterium lineatum* Ehrenb. var. *maximum* var. nov.
5. *Cosmarium portianum* Arch. var. *major* var. nov.
6. *Peridinium laeve* (Ruitf.) Hass. var. *wailesii* var. nov.
7. *Peridinium* sp. According to Wailes, closely related to *P. tabulatum*.

Zygospores not previously reported—*Cosmarium ovale* Ralfs. Zygospore with semi-cells.

SYSTEMATIC ARRANGEMENT OF ALGAL GROUPS AND SPECIES FOUND IN INDIANA

Class I—Myxophyceae

Aphanothece stagnina (Sprengel) A. Braun. Sullivan Co., July 24, 1930. Vigo Co., April, 1929.

[1]*Chroococcus minutus* (Kuetz) Näg. Vigo Co., 1928.

Chroococcus turgidus (Kuetz) Näg. Vigo Co., July 3 and July 18, 1929. Kosciusko Co., Aug. 31, 1929.

[1]*Chroococcus limneticus* Lemm. Kosciusko Co., Sept. 14, 1929. Vigo Co., Aug. 15, 1930.

[1]*Coelosphaerium nägelianum* Unger. Vigo Co., July 30, 1929. Kosciusko Co., Sept. 15, 1929.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Gloeocapsa arenaria* (hass.) Rabh. Vigo Co., July 9, 1929.

[1]*Gloeocapsa gelatinosa* Kuetz. Vigo Co., July 9, 1929.

[1]*Gloeocapsa muralis* Kuetz. Vigo Co., April, 1928.

Gloeocapsa polydermatica Kuetz. Vigo Co., April, 1928.

Gomphosphaeria aponina Kuetz. Montgomery Co., Aug. 14, 1929. Elkhart Co., Sept. 15, 1929.

[1]*Merismopedia elegans* A. Braun. Vigo Co., Spring, 1929, July 3, 1929, Aug. 14, 1930.

Merismopedia glauca (Ehrenb) Näg. Vigo Co., July 3, 1929, Aug. 15, 1930.

[1]*Merismopedia minima* Beck. Vigo Co., Aug. 31, 1931.

[1]*Merismopedia punctata* Meyen. Vigo Co., June 10, 1931, July 3, 1929, Aug. 4, 1930.

Microcystis aeruginosa Kuetz. Vigo Co., Aug. 4, 1930.

[2]*Microcystis aeruginosa* var. *major* (Wittr.) G. M. Smith. Vigo Co., Aug. 4, 1930.

[1]*Microcystis flos-aquae* (Wittr.) Kirch. Vigo Co., Aug. 13, 1930. Kosciusko Co., Sept. 15, 1929.

[1]*Microcystis parasitica* Kuetz. Wabash Co., Aug. 31, 1929.

[1]*Microcystis pseudofilamentosa* Craw. Kosciusko Co., Sept. 15, 1929.

Lyngbya aerugineo-caerulea (Kuetz) Com. Vigo Co., July 18, 1929.

[1]*Lyngbya arachnoidea* Kuetz. Vigo Co., July 3, 1929.

[1]*Lyngbya contorta* Lemm. Vigo Co., Aug. 23, 1930.

[1]*Lyngbya major* Menegh. Vigo Co., July 3, 1929, July 18, 1930.

[1]*Lyngbya martensiana* Menegh. Vigo Co., July 9, 1929.

[1]*Lyngbya putealis* Montague. Knox Co., Summer, 1929.

[1]*Oscillatoria anguina* Bory. Vigo Co., April 18, 1931. Tippecanoe Co., Sept. 23, 1929.

[1]*Oscillatoria angustissima* W. and G. S. West. Vigo Co., July 1, 1930.

Oscillatoria chalybea Mertens. Warren Co., Aug. 28, 1930.

[1]*Oscillatoria chlorina* Kuetz. Vigo Co., July 18, 1929.

Oscillatoria limosa Agardh. Benton Co., May 17, 1931. Vigo Co., April 11, 1931.

[1]*Oscillatoria okeni* Agardh. Vigo Co., July 23, 1930.

[1]*Oscillatoria ornata* Kuetz. Clay Co., July 4, 1929.

Oscillatoria princeps Vaucher. Vigo Co., July 23, 1930. Parke Co., July 13, 1929, February, 1928. Benton Co., May 17, 1931. Clay Co., May 23, 1931.

[1]*Oscillatoria proboscidea* Gom. Warren Co., Aug. 28, 1930.

[1]*Oscillatoria sancta* Kuetz. Montgomery Co., Aug. 4, 1929.

Oscillatoria splendida Brev. Vigo Co., July 23, 1930. Wabash Co., Aug. 31, 1929. Clay Co., July 4, 1929.

[1]*Oscillatoria subtilissima* Kuetz. Vigo Co., July 18, 1929.

Oscillatoria tenuis Agardh. Wabash Co., Aug. 31, 1929. Vigo Co., July 30, 1929.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Oscillatoria terebriformis* (Agardh.) Gomont. Vigo Co., April 20, 1929.

Phormidium tenue (Menegh) Gom. Sullivan Co., May 2, 1931.

[1]*Phormidium retzii* (Ag.) Gom. Wabash Co., Aug. 31, 1929.

Borzia trilocularis Cohn. Montgomery Co., Aug. 4, 1929.

[1]*Spirulina gomontiana* (Setchell) Geitler. Vigo Co., July 23, 1930.

[1]*Spirulina major* Kuetz. Vigo Co., July 23, 1930.

[1]*Spirulina princeps* (W. & G. S. West) G. S. West. Vigo Co., July 3, 1929, Aug. 13, 1930. Clay Co., May 23, 1931.

[3]*Trichodesmium thisbautii* Gom. Vigo Co., July 24, 1930.

[1]*Anabaena affinis* Lemm. Vigo Co., July 18, 1929.

[1]*Anabaena californica* Borge. Sullivan Co., May 24, 1931. Vigo Co., July 12, 1929.

[1]*Anabaena catenula* (Kuetz) Born and Flah. Greene Co., May 2, 1931. Vigo Co., July 18, 1929.

Anabaena flos-aquae (Lyngh.) Breb. Vigo Co., July 30, 1929.

[1]*Anabaena inaequalis* (Kuetz) Born and Flah. Montgomery Co., July 14, 1929.

[1]*Anabaena laxa* A. Braun. Vigo Co., June 18, 1929.

[1]*Anabaena limnetica* G. M. Smith. Kosciusko Co., Sept. 15, 1929.

[1]*Anabaena macrospora* var. *crassa.* Klebahn. Vigo Co., Aug. 15, 1930.

[2]*Anabaena macrospora* Klebahn var. *robusta* Lemm. Vigo. Co., July 3, 1929.

[1]*Anabaena plantonica* Brunthaler. Wabash River, August, 1930.

[1]*Anabaena poulseniana* Boye P. Vigo Co., June 27, 1930.

[1]*Anabaena scheremetievi* Flenkin. Montgomery Co., July 14, 1929.

[1]*Anabaena spiroides* Kelbahn var. *crassa* Lemm. Vigo Co., July 3, 1930.

[1]*Anabaena sphaerica* Born and Flah. Vigo Co., July 3, 1930.

Anabaena variabilis Kuetz. Vigo Co., June 6, 1931.

[3]*Anabaenopsis raciborskii* Wolosz. Vigo Co., Aug. 31, 1930.

[1]*Anabaenopsis circularis* (G. S. West) Wolosz. Vigo Co., Aug. 23, 1930.

Aphanizomenon flos-aquae (1) Ralfs. Vigo Co., Aug. 13, 1930, Vigo Co., July 17, 1930.

[1]*Cylindrospermum musciola* Kuetz. Sullivan Co., June 8, 1931.

[1]*Cylindrospermum majus* Kuetz. Vigo Co., during Summer, 1913.

[1]*Cylindrospermum minutissimum* Collins. Vigo Co., July 24, 1930.

[1]*Cylindrospermum minutum* Wood. Vigo Co., June 27, 1930.

[1]*Cylindrospermum stagnale* (Kuetz) Born and Flah. Vigo Co., July 30, 1929.

Nostoc coeruleum Lyngbya. Vigo Co., summer, 1928.

Nostoc commune Vaucher. North Terre Haute, Summer, 1928. Montgomery Co., Summer, 1925.

[1]*Nostoc linckia* (Roth) Bornet. Vigo Co., Summer, 1928.

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[2] Variety—not previously reported from State.

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[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Nostoc punctiforme* (Kuetz) Hariot. Montgomery Co., July 6, 1930. Vigo Co., April 24, 1930.

Nostoc pruniforme Ag. Fish hatcheries, Lake Wawasee. These colonies were very large, up to 2.5 centimeters in diameter and the bottom of the fish pond was literally covered with them.

[1]*Calothrix stagnalis* Gom. Vigo Co., 1928.

[1]*Calothrix sandwicensis* (Nordst.) Schmidle. Vigo Co., Aug. 1, 1929.

[3]*Dichothrix gypsophila* (Kuetz) Born and Flah. Kosciusko Co., Sept. 15, 1929.

[1]*Gloeotrichia echinulata* (J. E. Smith) Richt. Vigo Co., July 7, 1930 and July 9, 1930.

Gloeotrichia natans (Hedw.) Rabenh. Vigo Co., July 9, 1930.

[3]*Hammatoida normanii* W. and G. S. West. Vigo Co., June 26, 1929.

[1]*Rivularia minutula* (Kuetz) Born and Flah. Wabash Co., Aug. 31, 1929.

Rivularia echinulata (Smith) Born and Flah. Monroe Co., June 27, 1929.

Rivularia natens (Hedwig) Welwitach. Grant Co., Sept. 2, 1929.

[1]*Rivularia borealis* Richt. Wabash Co., Aug. 31, 1929.

[1]*Scytonema mirable* (Dillwyn) Born. Vigo Co., Aug. 1, 1929, and July 17, 1930.

Tolypothrix lanata (Desv.) Wartmann. Kosciusko Co., Sept. 15, 1929. Vigo Co., April, 1929.

Tolypothrix tenuis Kuetz. Vigo Co., 1928.

Tolyopthrix distorta (Desv.) Wartm. Vigo Co., July 17, 1930.

[3]*Desmonema wrangelii* (Ag.) Born and Flah. Vigo Co., Aug. 31, 1931.

[3]*Plectonema tenue* Thuret. Vigo Co., 1929.

Class III—Rhodophyceae

Batrachospermum moniliforme Roth. Montgomery Co., Spring, 1917.

Lemanea torulosa (Roth.) Ag. Owen Co., May, 1923. Collected by Glenn W. Bladyes of Ohio State University.

Class IV—Heterokontae

Botryococcus braunii Kuetz. Creek, one mile north of Brazil, State Road 49, May 31, 1931.

[1]*Botryococcus protuberans* W. and G. S. West var. *minor* G. M. Smith. Vigo Co., July 18, 1929.

[1]*Botryococcus sudeticus* Lemm. Vigo Co., July 9, 1930.

[1]*Ophiocytium capitatum* Wolle. Vermillion Co., June 6, 1931.

Ophiocytium cochleare A. Braun. Tippecanoe Co., Sept. 23, 1929. Sullivan Co., May 24, 1931.

[1]*Ophiocytium mains* Nägeli. Elkhart Co., Sept. 15, 1929.

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[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

Tribonema bombycinum (Ag.) Derb. and Sol. Vigo Co., May 17, 1931.

Botrydium granulatum (L) Grev. Tippecanoe Co., Summer, 1929. Vigo Co., Summer, 1930.

Class V—Chlorophyceae

[1]*Eudorina elegans* Ehrenb. Vigo Co., June 26, 1929. Sullivan Co., Aug. 21, 1930.

Gonium pectorale Müll. Vigo Co., June 26, 1929.

Pandorina morum (Müll.) Bury. Parke Co., July 20, 1929. Vigo Co., Aug. 14, 1930.

Pleodorina californica Shaw. Vigo Co., Aug. 13, 1930.

Pleodorina illinoiensis Kofoid. Howard Co., Sept. 2, 1929.

Volvox globator (L.) Ehrenb. Vigo Co., 1923. Kosciusko Co., Sept. 14, 1929.

[1]*Volvox mononae* G. M. Smith. Vigo Co., March 28, 1929.

Volvox aureus Ehrenb. Vigo Co., March 28, 1929.

[1]*Chlamydomonas angulosa* Dill. Vigo Co., May 2, 1931.

[3]*Carteria klebsii* (Dangeard) Dill. Vigo Co., Summer, 1929.

[3]*Asterococcus limneticus* G. M. Smith. Putnam Co., May 23, 1931.

Asterococcus superbus (Cienk) Scherffel. Montgomery Co., May 13, 1930.

Sphaerocystis schroeteri Chod. Vigo Co., Aug. 8, 1930. Kosciusko Co., Sept. 15, 1929.

Tetraspora gelatinosa (Vauch) Desv.

[1]*Tetraspora limnetica* W. and G. S. West. Vigo Co., June 30, 1930.

[1]*Tetraspora lacustris* Lemm. Marion Co., June 4, 1930.

Hydrodictyon reticulatum (1) Lagerh. Vigo Co., June 30, 1929. Very abundant and in all stages of development from zoospores to very large coenobia.

Pediastrum boryanum (Turpin) Menegh. Vermillion Co., June 6, 1931. Vigo Co., July 18, 1929. Kosciusko Co., Sept. 15, 1929.

[2]*Pediastrum boryanum* var. *longicorne* Raciborski. Vigo Co., July 18, 1929. Kosciusko Co., Sept. 14, 1929.

Pediastrum duplex Mayen. Vigo Co., Fall, 1927.

[2]*Pediastrum duplex* var. *clathratum* (A. Braun.) Lagerheim. Vigo Co., Aug. 4, 1930.

[2]*Pediastrum duplex* var. *gracillimum* W. and G. S. West. Vigo Co., Aug. 23, 1930.

[2]*Pediastrum duplex* var. *rotundatum* Lucks. Vigo Co., July 18, 1929.

[1]*Pediastrum integrum* Naeg. Tippecanoe Co., Sept. 23, 1929. Vigo Co., June 10, 1931. Sullivan Co., July 24, 1930.

[1]*Pediastrum ovatum* (Ehr.) A. Br. Vigo Co., Aug. 23, 1930.

[1]*Pediastrum sculptatum* G. M. Smith. Kosciusko Co., Sept. 14, 1929.

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[5] New Varieties.

[2]*Pediastrum simplex* var. *duodenarium* (Bailey) Robenhorst. Vermillion Co., June 6, 1931. Vigo Co., Aug. 4, 1930.

[2]*Pediastrum simplex* Meyen. var. *granulatum* Lemm. Kosciusko Co., Sept. 14, 1929.

Pediastrum tetras (Ehr.) Ralfs. Vermillion Co., June 6, 1931. Kosciusko Co., Sept. 14, 1929.

[3]*Characium naegellii* var. *majus* Hanagirg. Montgomery Co., May 13, 1930.

Characium pringsheimii A. Br. Kosciusko Co., Sept. 14, 1929.

[3]*Chlorococcum humicolum* (Naeg.) Rabenh. Sullivan Co., May 23, 1931.

[3]*Phyllobium sphagnicola* G. S. West. Vigo Co., May 17, 1931.

Dictyosphaerium ehrenbergianum Naeg. Montgomery Co., May 13, 1930.

[1]*Dictyosphaerium pulchellum* Wood. Vigo Co., Aug. 31, 1930.

[3]*Actinastrum hantzschii* Lagerh. Vigo Co., Aug. 4, 1930.

[2]*Actinastrum hantzschii* var. *fluvitale* Lemm. Vigo Co., Aug. 23, 1930.

[1]*Ankistrodesmus chodati* (Tanner-Fullemann) Brunnth. Vigo Co., Aug. 20, 1930.

[2]*Ankistrodesmus falcatus* var. *mirabilis* G. S. West. Sullivan Co., June 8, 1931. Kosciusko Co., Sept. 14, 1929. Vermillion Co., June 6, 1931.

[2]*Ankistrodesmus falcatus* var. *spirilliformis* G. S. West. Sullivan Co., July 24, 1930. Vigo Co., June 30, 1930.

[1]*Ankistrodesmus nitzschioides* G. S. West. Vigo Co., Aug. 4, 1930.

[1]*Ankistrodesmus setigerus* (Schröd) G. S. West. Parke Co., May 5, 1931. Sullivan Co., June 8, 1931.

[1]*Ankistrodesmus spiralis* (Turner) Lemm. Parke Co., June 18, 1929.

Chlorella vulgaris Beijer. Vigo Co., Aug. 17, 1930.

[3]*Closteriopsis longissimum* var. *aciculare* (Chod.). Vigo Co., Aug. 17, 1930.

Coelastrum microporum Nägeli. Parke Co., May 5, 1931. Montgomery Co., Sept. 8, 1929. Vigo Co., July 17, 1929. Noble Co., Sept. 15, 1929.

[1]*Coelastrum reticulum* (Dangeard) Senn. Vigo Co., Aug. 23, 1930.

Coelastrum sphaericum Naeg. Vermillion Co., June 6, 1931. Parke Co., May 5, 1931.

[1]*Crucigenia cruciata* (Wolle) Schmidle. Vigo Co., Aug. 23, 1930.

[1]*Crucigena apiculata* Lemm. Kosciusko Co., Sept. 14, 1929.

[1]*Crucigenia quadrata* Morren. Vermillion Co., June 6, 1931.

[1]*Crucigenia rectangularis* (Naeg) Gay. Vigo Co., July 18, 1929. Kosciusko Co., Sept. 15, 1929.

Crucigenia tetrapedia (Kirchner) W. and G. S. West. Vigo Co., Aug. 4, 1930.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Crucigenia truncata* G. M. Smith. Vigo Co., Aug. 23, 1930.

[3]*Elaktothrix viridis* (Snow) Printz. Vigo Co., July 17, 1930.

[3]*Gloeotaenium loitlesbergerianum* Hansgirg. Sullivan Co., July 24, 1930. Howard Co., Sept. 2, 1929. Vigo Co., July 17, 1930.

[3]*Kirchneriella lunaris* (Kirchner) Möbius. Kosciusko Co., Sept. 14, 1929. Vigo Co., Aug. 15, 1930.

[1]*Kirchneriella obesa* (W. West) Schmidle. Montgomery Co., May 13, 1930.

[2]*Kirchneriella obesa* var. *major* (Bunard) G. M. Smith. Sullivan Co., June 8, 1931.

[2]*Kirchneriella obesa* var. *aptera* (Teiling) Brunnthaler. Vigo Co., Aug. 31, 1930.

[3]*Micractinium pusillum* Fresen. var. *elegans* G. M. Smith. Vigo Co., Aug. 23, 1930.

[3]*Oocystis borgei* Snow. Vigo Co., Aug. 15, 1930, July 9, 1929.

[1]*Oocystis crassa* Wittr. Vigo Co., June 8, 1931.

[1]*Oocystis elliptica* W. West. Parke Co., June 18, 1929.

[1]*Oocystis natans* (Lemm.) Wille. Grant Co., Sept. 2, 1929.

[2]*Oocystis natans* var. *major* G. M. Smith. Vigo Co., June 10, 1931.

[1]*Oocystis parva* W. & G. S. West. Vigo Co., July 26, 1930.

[1]*Oocystis pusilla* Hansgirg. Sullivan Co., May 24, 1931.

[1]*Oocystis solitaria* Wittr. Montgomery Co., Sept. 8, 1929.

Scenedesmus abundans (Kirchner) Chodat. Sullivan Co., June 8, 1931.

[2]*Scenedesmus acuminata* (Lag.) Chod. var. *elongatus* G. M. Smith. Vigo Co., Aug. 31, 1931.

[2]*Scenedesmus arcuatus* var. *capitatus* G. M. Smith. Vigo Co., May, 1930.

[1]*Scenedesmus arcuatus* var. *platydisca* G. M. Smith. Vigo Co., Aug. 23, 1930, July 18, 1929. Parke Co., May 5, 1931.

[1]*Scenedesmus bernardi* G. M. Smith. Parke Co., May 5, 1931.

[2]*Scenedesmus bijuga* (Turp.) Lagerh. var. *flexosus* Lemm. Vigo Co., Aug. 4, 1930. Many of these colonies had 32 cells instead of the usual 16 cells.

[2]*Scenedesmus bijuga* var. *irregularis* (Wille) G. M. Smith. Vigo Co., May, 1930.

[1]*Scenedesmus bijuga* var. *alternans* (Reinsch) Borge. Kosciusko Co., Sept. 15, 1929.

[2]*Scenedesmus bijuga* var. *alternans* forma *irregularis* G. M. Smith. Vigo Co., May, 1930.

[1]*Scenedesmus denticulatus* Lagerheim. Howard Co., Aug. 30, 1929.

[2]*Scenedesmus denticularis* var. *linearis* Hanag. Vigo Co., May, 1930.

Scenedesmus dimorphus (Turp.) Kuetz. Vigo Co., Aug. 23, 1930.

[1]*Scenedesmus longus* Mayen. Howard Co., Aug. 30, 1930.

[2]*Scenedesmus longus* var. *brevispina* G. M. Smith. Vigo Co., June 3, 1930.

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[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] **New Varieties.**

[1]*Scenedesmus opoliensis* P. Richter. Parke Co., May 5, 1931. Vigo Co., Aug. 15, 1930.

Scenedesmus quadricauda (Turp.) de Breb. Vigo Co., June 30, 1929.

[2]*Scendesmus quadricauda* var. *parvus* G. M. Smith. Vigo Co., no date.

[2]*Scenedesmus quadicauda* var. *quadrispina* (Chod.) G. M. Smith. Parke Co., May 5, 1931.

[2]*Scenedesmus quadricauda* var. *westii* G. M. Smith. Parke Co., May 5, 1931.

[2]*Scenedesmus quadricauda* var. *longispina* (Chod.) G. M. Smith. Vigo Co., Aug. 4, 1930.

[4]*Scenedesmus quadricauda* var. *africana* Fritsch and Rich. Vigo Co., Aug. 31, 1930.

[3]*Selenastrum westii* G. M. Smith. Vigo Co., Aug. 23, 1930.

[1]*Sorastrum americanum* (Bohlin) Schmidle var. *undulatum* G. M. Smith. Vigo Co., July 17, 1930.

Sorastrum spinulosum Nägeli. Montgomery Co., Sept. 8, 1929. Vigo Co., July 12, 1929. Sullivan Co., May 24, 1931. Kosciusko Co., Sept. 14, 1929.

[1]*Tetraedron caudatum* (Corda) Hanag. Sullivan Co., June 8, 1931.

[2]*Tetraedron gracile* (Reinsch) Hanag. var. *excavatum* G. M. Smith. Vigo Co., June 30, 1930.

Tetraedron minimum (A. Braun) Hanag. Parke Co., June 18, 1929. Vermillion Co., June 6, 1931.

[2]*Tetraedron regulare* Kuetz. forma *major* Reinsch. Martin Co., Nov. 17, 1929.

[2]*Tetraedron trigonum* (Nägeli) Hanag. var. *gracile* (Reinsch) de Toni. Vigo Co., Aug. 23, 1930, Aug. 11, 1930.

[1]*Tetraedron tunidulum* (Reinsch) Hanag. Vigo Co., July 17, 1930. Differs from the drawings of this species in that it has wart-like thickenings, (not spines) at the apices.

[1]*Tetrastrum elegans* Playf. Vigo Co., Aug. 23, 1930.

[1]*Tetrastrum heterocanthum* (Nordet) Chod. Vigo Co., Aug. 4, 1930.

[1]*Tetrastrum staurogeniaeforme* (Schröd) Lemm. Vigo Co., Aug. 23, 1930.

[1]*Treubaria triappendiculata* Bern. Vigo Co., Aug. 23, 1930, Aug. 11, 1930.

[3]*Geminella ordinata* (W. & G. S. West) Heering. Vigo Co., May 13, 1931.

[1]*Geminella interrupta* Turpin. Kosciusko Co., Sept. 15, 1929.

Ulothrix aequalis Kuetz. Vigo Co., July 3, 1930.

Ulothrix tenuissima Kuetz. Vigo Co., July 3, 1930.

[1]*Ulothrix variabilis* Kuetz. Knox Co., April 23, 1930. Vigo Co., May 22, 1931, June 24, 1930.

Ulothrix zonata Kuetz. Montgomery Co., June 6, 1930.

Schizomeris leibleinii Kuetz. Knox Co., June 23, 1929.

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[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

Microspira stagnorum (Kuetz.) Lagerh. Parke Co., February, 1928.

[1]*Microspira tumidula* Hazen. Vigo Co., April 23, 1930.

[3]*Prasiola crispa* (Lightf.) Menegh. forma *muralis* (Kuetz) G. S. West. Vigo Co., July 3, 1930.

[3]*Cylindrocapsa geminella* Wolle. Clay Co., July 7, 1930.

Pleurococcus naegelii Chod. Common everywhere on north side of trees.

Chaetophora elegans (Roth) Ag. Vigo Co., April 23, 1930. Marion Co., June 4, 1930.

Chaetophora incrassata (Hudson) Hazen. Vigo Co., April 24, 1930.

Chaetophora pisiformis (Roth) Ag. Sullivan Co., June 8, 1931. Vigo Co., June 18, 1929.

Draparnaldia glomerata (Vauch.) Ag. Vermillion Co., June 6, 1931.

Draparnaldia plumosa (Vauch.) Agardh. Vigo Co., Spring, 1929.

[1]*Drapernaldia ravenelii* Wolle. Vigo Co., April 24, 1930.

[1]*Microthamnion kutzingianum* Naeg. Vigo Co., May 9, 1931.

[1]*Microthamnion strictissimum* Rabenh. Vigo Co., May 9, 1931.

[1]*Stigeoclonium lubricum* (Dillw.) Kuetz. Kosciusko Co., September 15, 1929.

Stigeoclonium tenue (Ag.) Kuetz. Vigo Co., June 20, 1929.

[2]*Stigeoclonium tenue* var. *bulbiferum* Wolle. Vigo Co., April 24, 1930.

[1]*Aphanochaete repens* A. Br. Clay Co., May 23, 1931.

[3]*Coleochaete scutata* Breb. Vigo Co., spring of 1929.

[1]*Coleochaete soluta* (Breb.) Pringh. Vigo Co., spring of 1929.

[3]*Basicladia chelonum* (Collins.) Hoffman and Tilden. Vigo Co., June, 1929.

Cladophora crispata (Roth) Kuetz. Parke Co., spring, 1930.

Cladophora glomerata (L) Kuetz. Vigo Co., spring, 1930.

[2]*Cladophora glomerata* var. *clavata*. Wolle. Vigo Co., June, 1931.

[1]*Cladophora sauteri* (Nees) Kuetz. Kosciusko Co., June 12, 1931. Sometimes listed as *Aegagropila sauteri* (Nees) Kuetz.

[1]*Pithophora varia* Wille. Noble Co., September 15, 1929. Vigo Co., May, 1931. Clay Co., June 12, 1930. Tippecanoe Co., September 23, 1929. Monroe Co., June 27, 1929. Montgomery Co., September 7, 1929.

[1]*Pithophora oedogonia* Wittr. var. *polyspora* Rendle and West. This species developed in the laboratory culture and seemed to differ from *P. varia* in that many of the *aplanospores* were *globose*.

[1]*Rhizoclonium hieroglyphicum* Kuetz. Vigo Co., spring, 1929.

[3]*Dichotomosiphon tuberosus* (A. Br.) Ernst. Lagrange Co., Sept. 15, 1929.

Vaucheria geminata (Vauch.) de Candolle. Vigo Co., June 10, 1931. Montgomery Co., April 23, 1930. Marion Co., April 22, 1930. Greene Co., May 2, 1931.

Vaucheria geminata forma *racemosa* (Vauch.) Walz. Vigo Co., April 4, 1931.

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[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Vaucheria hamata* (Vauch.) de Candolle. Vigo Co., April 11, 1931.

[1]*Vaucheria longipes* Collins. Vigo Co., Oct. 30, 1929.

[5]*Vaucheria orthocarpa* (Reinsch) var. *major* var. nov. Vigo Co., 1929. Much larger than the species, otherwise in agreement with figure and description. Oogonia 97-98u x 147-175u; oospore 85-96u x 107-125. Very few oospores were as short as 107u.

[1]*Vaucheria pachyderma* Walz. Marion Co., April 22, 1930. Warren Co., May 17, 1931. Henry Co., April 22, 1930.

[1]*Vaucheria polysperma* Hassell. Vigo Co., April 24, 1930.

[1]*Vaucheria repens* Hassell. Vermillion Co., June 6, 1931.

Vaucheria sessilis (Vauch.) de Candolle. Vigo Co., May 17, 1931. Vermillion Co., June 1, 1931. Marion Co., April 28, 1931. Sullivan Co., May 2, 1931.

[2]*Vaucheria sessilis* forma *genuina* Hansgirg. Vigo Co., May 13, 1931.

Vaucheria terrestris de Candolle. Montgomery Co., August 26, 1929. Putnam Co., May 23, 1931. Sullivan Co., June 8, 1931. Vigo Co., spring, 1929.

[4]*Vaucheria uncinata* Kuetz. Vigo Co., May 14, 1931. Previously reported from Norway and Europe.

[1]*Bulbochaete basispora* Wittr. and Lund. Vigo Co., April 23, 1930. Previously reported from Ohio and Sweden.

[1]*Bulbochaete crenulata* Pringh. Vigo Co., Aug. 12, 1929.

Bulbochaete intermedia De Bary. Montgomery Co., April 23, 1930. Knox Co., May 26, 1926.

[2]*Bulbochaete intermedia* var. *depressa* Wittr. Montgomery Co., April 23, 1930.

[1]*Bulbochaete rectangularis* Wittr. Vigo Co., May 13, 1931. Greene Co., May 12, 1931. Knox Co., May 26, 1926.

[1]*Bulbochaete repanda* Wittr. Greene Co., May 10, 1931.

[1]*Bulbochaete varians* Wittr. Montgomery Co., Sept. 8, 1929. Greene Co., May 12, 1931.

[4]*Oedogonium armigerum* Hirn. Montgomery Co., June 6, 1930. Previously reported from Brazil.

[4]*Oedogonium biforme* Nordst. Knox Co., May 17, 1931.

[1]*Oedogonium borisianum* (Le Clerc) Witter. Montgomery Co., June 6, 1930. Vigo Co., July 12, 1929. Clay Co., July 7, 1930.

[2]*Oedogonium borisianum* var. *westii* Tiffany and Brown. Vigo Co., May 9, 1931.

[5]*Oedogonium borisianum* var. *minus* L. H. Tiffany and B. H. Smith var. nov. Vigo Co., June 26, 1929. Oogonium 33-55u x 33-55u. Oospore 30-33u x 37-42u. Pore—superior. Suffultory cell—30u x 52u. Vegetative cells—14-15u x 37-48u. Dwarf males present.

[1]*Oedogonium boscii* (Le Clerc) Wittr. var. *occidentale* Hirn. Greene Co., May 2, 1931.

[1]*Oedogonium capilliforme* Kuetz. Wittr. Vermillion Co., June 1, 1931. Montgomery Co., June 6, 1930.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[2]*Oedogonium capilliforme* var. *diversum* (Hirn) Tiffany. Clay Co., May 22, 1931.

[1]*Oedogonium capilliforme* var. *australe* Wittr. Montgomery Co., Aug. 26, 1929. Vigo Co., May 14, 1931.

[1]*Oedogonium ciliatum* (Hass.) Pringsheim. Knox Co., May 26, 1926.

[1]*Oedogonium capillare* (Linnaeus) Kuetz. Parke Co., June 17, 1929. Vigo Co., June 18, 1929.

[2]*Oedogonium capillare* forma *stagnale* (Kuetz: Wittr.) Hirn. Parke Co., June 17, 1929.

[1]*Oedogonium cardiacum* (Hess.) Wittr. Montgomery Co., June 6, 1930.

[2]*Oedogonium cardiacum* var. *carbonicum* Wittr. Vigo Co., May 14, 1931.

[2]*Oedogonium cardiacum* (Hass.) Wittr. var. *minus* Lemm. Putnam Co., May 23, 1931. Vigo Co., June 10, 1931.

[1]*Oedogonium concatenatum* (Hass.) Wittr. Vigo Co., April 23, 1930.

[2]*Oedogonium crassiusculum* Wittr. var. *idioandrosporum* Nordst. and Wittr. Sullivan Co., June 28, 1929. Vigo Co., June 19, 1929. Knox Co., May 26, 1926.

[2]*Oedogonium crassiusculum* var. *cataractum* (Wolle) Tiffany. Vigo Co., May 28, 1931.

[4]*Oedogonium crassiusculum* var. *arechavaletae* (Wittr.) Hirn. Sullivan Co., May 2, 1931. Clay Co., May 31, 1931.

[1]*Oedogonium crenulatocostatum* Wittr. Vigo Co., July 12, 1929.

[2]*Oedogonium crenulatum* Wittr. var. *gracillus* Nordst. and Hirn. Sullivan Co., June 28, 1929.

[1]*Oedogonium crispum* (Hass.) Wittr. Knox Co., May 26, 1926.

[1]*Oedogonium curvum* Pringh. Knox Co., May 26, 1926.

[1]*Oedogonium cyathigerum* Wittr. Vigo Co., June, 1926.

[2]*Oedogonium cyathigerum* forma *perfectum* Hirn. Vigo Co., 1928.

[2]*Oedogonium cryptoporum* Wittr. var. *vulgare* Wittr. Montgomery Co., Sept. 8, 1929. Vigo Co., spring, 1929.

[2]*Oedogonium decipiens* Wittr. forma *dissimile* Hirn. Knox Co., May 26, 1926.

[1]*Oedogonium exocostatum* Tiffany. Vigo Co., July 12, 1927.

[1]*Oedogonium fragile* Wittr. Knox Co., May 26, 1926.

[1]*Oedogonium globosum* Nordst. Montgomery Co., May 13, 1930.

Oedogonium grande Kuetz. Wittr. Vigo Co., June 18, 1929.

[2]*Oedogonium grande* var. *aequatoriale* Wittr. Knox Co., May 26, 1926.

[2]*Oedogonium grande* var. *majus* Hansgirg. Vigo Co., June 26, 1929. Much larger than recorded variety measurements. Oogonium 59-63u x 81-96u. Oospore 52-59u x 74-88u. Veg. cell 33-37u x 122-130u. Pore—superior. Male filament—33-37u wide.

[1]*Oedogonium gracillimum* Wittr. and Lund. Knox Co., May 26, 1926. Vigo Co., June 26, 1929. Montgomery Co., April 23, 1930.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[4]*Oedogonium inconspicum* Hirn. Montgomery Co., June 6, 1930.

[1]*Oedogonium intermedium* Wittr. Vigo Co., June 18, 1929; April 23, 1929.

[1]*Oedogonium iowense* Tiffany. Knox Co., May 26, 1926.

Oedogonium irregulare Wittr. Vigo Co., May 17, 1931.

Oedogonium landsboroughi (Hass.) Wittr. Monroe Co., June 29, 1929.

[2]*Oedogonium landsboroughi* var. *norvegicum* Wittr. Vigo Co., June 26, 1929.

[1]*Oedogonium latiusculum* Tiffany. Vigo Co., summer, 1929.

[1]*Oedogonium mexicanum* Wittr. Vigo Co., July 4, 1929.

[1]*Oedogonium monile* Berkley and Harvey. Putnam Co., May 23, 1931.

[1]*Oedogonium moniliforme* Wittr. Vigo Co., July 12, 1929.

[1]*Oedogonium multisporum* Wood. Vigo Co., May 13, 1931. Davis Co., May 23, 1931.

[1]*Oedogonium oblongum* Wittr. Knox Co., May 26, 1926. Vigo Co., June 26, 1929.

[1]*Oedogonium paludosum* (Hass.) Wittr. Knox Co., May 26, 1926.

[2]*Oedogonium paludosum* var. *parvisporum* Hirn. Knox Co., May 26, 1926. Clay Co., May 23, 1931.

[1]*Oedogonium paucocostatum* Transeau. Vigo Co., Aug. 13, 1930.

[4]*Oedogonium paulense* Nordst. and Hirn. Greene Co., May 2, 1931. Clay Co., May 23, 1931. Measurements differ enough from the species that a new variety might well be made. Vegetative cells 14-20u x 85u; oogonium 37-44u x 55-78u; oospore 34-41u x 41-54u. Antheridia present. No antheridia were found in the Greene County collections, the determination being based on the oogonia, oospores and vegetative cells which were quite characteristic for the species. Reported previously from Brazil and Australia.

[1]*Oedogonium pisanum* Wittr. Parke Co., May 5, 1931.

[2]*Oedogonium pisanum* var. *gracilis* Transeau and Tiffany. Knox Co., May 17, 1931.

[1]*Oedogonium plagiostomum* Wittr. Sullivan Co., June 21, 1929. Clay Co., May 31, 1931.

[2]*Oedogonium plagiostomum* var. *gracilius* Wittr. Vigo Co., June 28, 1929. Knox Co., June 23, 1930.

[1]*Oedogonium plusiosporum* Wittr. Sullivan Co., June 21, 1929.

[1]*Oedogonium porrectum* Nordst. and Hirn. Knox Co., May 26, 1926.

[1]*Oedogonium pratense* Transeau. Knox Co., May 26, 1926. Vigo Co., June 26, 1929.

[1]*Oedogonium princeps* (Hass.) Wittr. Vigo Co., May 17, 1931.

Oedogonium pringsheimii Cramer; Wittr. Knox Co., June 23, 1929.

[2]*Oedogonium pringsheimii* var. *nordstedtii*. Knox Co., June 23, 1929.

[2]*Oedogonium pringsheimii* (Cramer; Wittr.) var. *abbreviatum* Hirn. Vigo Co., April 23, 1930.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Oedogonium pseudacrosporum* Wittr. Vigo Co., June 26, 1929.

[1]*Oedogonium richterianum* Lemm. Knox Co., May 26, 1926.

[1]*Oedogonium rivulare* (Le Clerc) A. Braun. Vigo Co., June 25, 1930.

[1]*Oedogonium richterianum* Lemm. Knox Co., May 26, 1926.

[2]*Oedogonium rufescens* var. *exiguum* (Elfving) Tiffany. Montgomery Co., Aug. 4, 1929.

[2]*Oedogonium rufescens* var. *lundellii* (Wittr.) Tiffany. Sullivan Co., May 26, 1931.

[2]*Oedogonium rugulosum* (Nordst.) forma *minutum* (Hanag.) Hirn. Montgomery Co., June 6, 1930.

[1]*Oedogonium suecicum* Wittr. Knox Co., May 2, 1931. Vigo Co., spring, 1929.

[5]*Oedogonium suecicum* var. *australe* (G. S. West) B. H. Smith nov. comb. Knox Co., May 2, 1931. There is enough difference between the species and the form *australe* G. S. West as exhibited by this material to raise the varietal rank. Oogonium 37-41u x 47u. Oospore 37u x 34-37u without spines. Oospore 30-34u x 34-37u without spines. Vegetative cells 17-20u x 53-58u.

[1]*Oedogonium sexangulare* Cleve. Montgomery Co., June 6, 1930. Vigo Co., June 26, 1929. Specimens smaller than the type species. Oogonium 33u x 30-32u. Oospore 26u x 26-28u. Pore—median. Vegetative cells 15u x 37-63u. Dwarf males present.

[1]*Oedogonium varians* Wittr. and Lund. Knox Co., June 23, 1929. Dioscious form.

[1]*Oedogonium vaucherii* (Le Clerc) A. Br. Wittr. Vigo Co., July 3, 1929.

[1]*Oedogonium verrucosum* Hallas. Montgomery Co., Sept. 8, 1929.

Oedogonium wabashense Tiffany. Knox Co., 1927.

[1]*Oedogonium wyliei* Tiffany. Montgomery Co., Aug. 27, 1929.

[3]*Debarya decussata* Transeau. Vigo Co., April 26, 1929.

Mougeotia genuflexa (Dillwyn) Agardh. Vigo Co., April 23, 1930.

[1]*Mougeotia laetevirens* (Braun) Wittr. Montgomery Co., Sept. 8, 1929.

[1]*Mougeotia pulchella* Wittr. Vigo Co., April 23, 1929.

[1]*Mougeotia robusta* (De Bary) Wittr. Vermillion Co., June 1, 1931. Sullivan Co., April 26, 1930. Vigo Co., April 23, 1930; June 10, 1930.

[2]*Mougeotia robusta* var. *biornata* Wittr. Sullivan Co., April 25, 1930. Vigo Co., April 23, 1930.

Mougeotia scalaris Hassall. Vigo Co., June 10, 1931.

[1]*Mougeotia sphaerocarpa* Wolle. Vermillion Co., June 1, 1931. Aplanospores abundant but no zygospores.

[1]*Spirogyra affinis* (Hass.) Petit. Vigo Co., May 14, 1931.

[1]*Spirogyra borgeana* Transeau. Montgomery Co., April 23, 1930. Putnam Co., May 23, 1931.

[4]*Spirogyra bucheti* Petit. Sullivan Co., July 11, 1930. Previously reported from Morocco.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Spirogyra catenaeformis* (Hass.) Kuetz. Vigo Co., April 24, 1931. Decatur Co., April 22, 1930. Sullivan Co., July 11, 1930. Aplanospores present.

[2]*Spirogyra catenaeformis* var. *parvula* Transeau. Vigo Co., April 23, 1930; April 24, 1931.

Spirogyra communis (Hass.) Kuetz. Vigo Co., April 24, 1931; April 23, 1930.

Spirogyra condensata (Vauch) Kuetz. Putnam Co., May 23, 1931. Vigo Co., April 11, 1931. Sterile cells inflated, a not previously reported characteristic of American specimens, although apparently common for European specimens.

Spirogyra crassa Kuetz. Knox Co., May 26, 1926.

Spirogyra decimina (Mueller) Kuetz. Vigo Co., April 24, 1931.

[2]*Spirogyra decimina* (Mueller) Kuetz var. *plena* W. and G. S. West. Sullivan Co., May 24, 1931. Vigo Co., April 24, 1930.

Spirogyra ellipsospora Transeau. Knox Co., May 27, 1931. Warren Co., May 17, 1931.

[1]*Spirogyra farlowii* Transeau. Vigo Co., April 23, 1930; April 24, 1931. Greene Co., May 2, 1931.

[1]*Spirogyra grevilleana* (Hass.) Kuetz. Vigo Co., April 24, 1931; April 18, 1931.

[1]*Spirogyra inconstans* Collins. 1912. *S. fallax* (Hansgirg) Wille 1900. Not. *S. insignis* var. *fallax*. Hansgirg Hedwigia 27, 1860; *S. wille* Skuja 1928. Sullivan Co., May 2, 1931.

Spirogyra inflata (Vauch.) Rab. Includes *S. frgida* Gay. Knox Co., May 26, 1926. Greene Co., May 4, 1931. Vigo Co., April 23, 1930; April 24, 1931. Material collected from Hulman Pond was reproducing by aplanospores.

[1]*Spirogyra juergensii* Kuetz. Benton Co., May 17, 1931. Greene Co., May 10, 1931. Vigo Co., April 23, 1930. Sullivan Co., April 25, 1930.

[1]*Spirogyra laxa* Kuetz. Clay Co., May 9, 1931.

Spirogyra longata (Vauch) Kuetz. Warren Co., May 17, 1931. Vigo Co., April 24, 1931; April 24, 1930. Knox Co., April 25, 1931.

Spirogyra majuscula Kuetz. Vigo Co., April 23, 1930; May 17, 1931; April 23, 1930. Sullivan Co., May 2, 1931. Clay Co., April 13, 1929. Putnam Co., May 23, 1931. That found on April 23, 1930—conjugation was both lateral and sclariform. Lateral conjugation rare. A very abundant and variable form.

[1]*Spirogyra maxima* (Hass.) Wittr. Vigo Co., no date given.

[4]*Spirogyra nawaschini* Kasanowsky. Montgomery Co., April 23, 1930. Conjugation was both lateral and sclariform. Immature aplanospores were also present. Previously reported from Europe.

Spirogyra neglecta Hass. Sullivan Co., June 7, 1931; July 11, 1930.

Spirogyra nitida (Dillw.) Link. Montgomery Co., July 14, 1929.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

Spirogyra porticalis (Mueller) Cleve. Vigo Co., May 14, 1931. Fertile cells short, spores greatly crowded, ovoid to globose ovoid. Vigo Co., April 24, 1931. Knox Co., April 25, 1930.

[1]*Spirogyra protecta* Wood. Clay Co., May 23, 1931. Sullivan Co., May 23, 1931. Vigo Co., April 24, 1930.

[1]*Spirogyra reflexa* Transeau. Vigo Co., June 30, 1929.

[1]*Spirogyra reticulata* Nordst. Vigo Co., April 23, 1930.

[1]*Spirogyra setiformis* (Roth) Kuetz. Montgomery Co., July 14, 1929.

[1]*Spirogyra singularis* Nordst. Vigo Co., April 23, 1930.

[1]*Spirogyra spreeiana* Rabenh. Vigo Co., April 23, 1930; April 24, 1930. Aplanospores lateral conjugation common in Hulman pond collection.

[1]*Spirogyra stictica* (E gl. Bot.) Wille. Vigo Co., June 8, 1929; June 26, 1929.

[4]*Spirogyra subreticulata* Fritsch. Sullivan Co., June 21, 1929. Montgomery Co., July 14, 1929.

[4]*Spirogyra schmidtii* W. & G. S. West. Clay Co., July 7, 1930. Zygospore 48-51u x 78-102u. Vegetative cell 31-34u x 221-357u. End wall—plain. Chromatophores 3, sometimes 4. Spores about 2 times as long as broad, usual type is 3 times as long as broad. Reticulete walls pronounced. Previously reported from Koh Chang, Siam.

[1]*Spirogyra tenuissima* (Hass.) Kuetz. Vigo Co., April 24, 1931. Montgomery Co., April 15, 1931.

[4]*Spirogyra tolosana* Comere. Clay Co., May 9, 1931. Vigo Co., May 24, 1931. Occasional cells have but one chromotophore. Measurements agree perfectly for the species. The fertile cells are longer, however, than the type. Comere describes the spores as filling the fertile cells. In this material the spores fill two-thirds of the fertile cell usually, sometimes only one-third or one-fourth of the cell. Previously reported from France.

Spirogyra varians (Hass.) Kuetz. Knox Co., April 25, 1930. Henry Co., April 22, 1930. Warren Co., May 17, 1931. Clinton Co., May 23, 1931. Vigo Co., April 23, 1930. A very common species. In this collection splanospores were forming. There was one instance of a perfectly mature zygospore formed in the male filament. Conjugation tube was still connected with the female filament.

[2]*Spirogyra varians* var. *minor* Teodoresco. Sullivan Co., June 28, 1929; May 23, 1930. Greene Co., May 2, 1931. Vigo Co., May 14, 1931; May 13, 1931. Henry Co., April 22, 1930.

[4]*Spirogyra velata* Nordstedt. Vigo Co., April 23, 1930.

[2]*Spirogyra velata* var. *occidentalis* Transeau. Knox Co., April 25, 1930; May 26, 1926. Benton Co., May 17, 1931. Montgomery Co., April 23, 1930.

Spirogyra weberi Kuetz. Benton Co., May 17, 1931. Warren Co., May 17, 1931. Clay Co., May 31, 1931. Vigo Co., May 13, 1931.

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[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Zygnema collinsianum* Transeau. Knox Co., May 26, 1926.

Zygnema cruciatum (Vaucher) Agardh. Sullivan Co., May 2, 1931. Greene Co., May 4, 1931. Vigo Co., June 26, 1929.

Zygnema insigne (Hassall) Kuetz. Vigo Co., April 23, 1930, June 10, 1931.

[1]*Zygnema cylindricum* Transeau. Knox Co., May 2, 1931. Greene Co., May 4, 1931. Aplanospores abundant in Knox Co. collection, but very few in Green Co. collection.

[1]*Zygnema laetevirens* Klebs. Greene Co., May 10, 1931. Parthenospores common.

[2]*Zygnema pectinatum* (Vauch.) Agardh. var. *crassum* Transeau. Vigo Co., May 30, 1930.

[1]*Zygnema peliosporum* Wittr. Collected by Dr. Donaghy in Vigo Co., no date given.

[1]*Zygnema stellinum* (Vaucher) Agardh. Vigo Co., April 23, 1930. Clay Co., May 23, 1931.

[1]*Zygnema vaucherii* Agardh. Vigo Co., April 23, 1926.

[2]*Gonatozygon monotaenium* De Bary. Montgomery Co., July 14, 1929.

[3]*Netrium digitus* (Ehrenb.) Itzigsh and Rothe. Sullivan Co., June 21, 1929. Monroe Co., summer, 1929. Vigo Co., May, 1930.

Arthrodesmus convergens Ehrenb. Montgomery Co., Sept. 8, 1929.

[1]*Closterium abruptum* West. Vigo Co., summer, 1930.

[2]*Closterium acerosum* (Schrank) Ehrenb. var. *elongatum* Breb. Clay Co., May 23, 1931.

[1]*Closterium archerianum* Cleve. Vigo Co., May, 1930.

[1]*Closterium cynthia* De Not. Knox Co., May 23, 1931.

[1]*Closterium decorum* Breb. Montgomery Co., Aug. 28, 1929. Figure shows formation of zygospore.

Closterium dianae Ehrenb. Montgomery Co., Sept. 20, 1929.

[4]*Closterium dianae* var. *arcuatum* (Breb.) Rabenh. Kosciusko Co., Sept. 15, 1929.

[1]*Closterium didymotocum* Corda. Montgomery Co., Sept. 8, 1929. Clay Co., May 23, 1931.

Closterium ehrenbergii Menegh. Vigo Co., Aug. 14, 1930. Sullivan Co., June 21, 1929. Koscuisko Co., Sept. 14, 1929.

[1]*Closterium gracile* Breb. Vigo Co., Aug. 20, 1930.

[1]*Closterium keutzingii* De Brebisson. Vigo Co., July 18, 1929. Montgomery Co., June 6, 1930.

[1]*Closterium leibleinii* Kuetz. Sullivan Co., June 8, 1931. Noble Co., Sept. 15, 1929.

Closterium lineatum Ehrenb. Tippecanoe Co., Sept. 23, 1929.

[5]*Closterium lineatum* Ehrenb. var. *maximum* var. nov. Montgomery Co., Sept. 20, 1929.

[1]*Closterium macilentum* Breb. Sullivan Co., April 25, 1930.

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[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

Closterium monilifernum (Bory) Ehrenb. Sullivan Co., June 8, 1931. Vermillion Co., June 6, 1931. Vigo Co., June 10, 1931. Wabash Co., Aug. 31, 1929.

[1]*Closterium pritchardianum* Arch. Vigo Co., April 23, 1930, July 9, 1930. Showing abundant zygospore formation. Plates show variations in conjugation. In second collection the material was proportionately larger, being 34-58u wide x 323-680u long. Apex 7-8u wide. Previously reported from United States in Connecticut.

Closterium setaceum Ehrenb. Vigo Co., July 12, 1929.

[1]*Closterium subulatum* (Kuetz) Breb. Vigo Co., May 20, 1929.

Closterium venus Kuetz. Noble Co., Sept. 15, 1929.

[2]*Cosmarium abbreviatum* Racib. var. *planctonicum* W. & G. S. West. Putnam Co., May 23, 1931.

[2]*Cosmarium abscissum* var. *subetchachanense.* Montgomery Co., Sept. 8, 1929.

[1]*Cosmarium binum* Nordst. Vigo Co., July 9, 1930.

[1]*Cosmarium bioculatum* Breb. Kosciusko Co., Sept. 14, 1929.

Cosmarium botrytis (Bory) Menegh. Vigo Co., Aug. 13, 1930. Parke Co., June 18, 1929.

[2]*Cosmarium botrytis* var. *subtumidum* Wittr. Sullivan Co., May 24, 1931.

[2]*Cosmarium biretum* Breb. var. *trigibbernum* Nordst. Vermillion Co., June 6, 1931.

[1]*Cosmarium bireme* Nordst. Vigo Co., July 26, 1930.

[1]*Cosmarium blytii* Wille. Sullivan Co., June 7, 1931. Clay Co., July 24, 1930, June 21, 1930.

[1]*Cosmarium circulare* Reinsch. Elkhart Co., Sept. 15, 1929.

[1]*Cosmarium calcareum* Wittr. Montgomery Co., Sept. 8, 1929.

Cosmarium dentatum Wolle. Sullivan Co., July 24, 1930. Vigo Co., June 3, 1930.

[1]*Cosmarium eloisanum* Wolle. Vigo Co., June 20, 1929.

[1]*Cosmarium formosulum* Hoff. Vermillion Co., June 6, 1931.

Cosmarium granatum Breb. Vermillion Co., June 1, 1931. Vigo Co., May, 1930.

Cosmarium granatum var. *subgranatum* Nordst. Sullivan Co., June 7, 1931.

[2]*Cosmarium granatum* var. *ocellatum* W. West and G. S. West. Sullivan Co., July 24, 1930. 41-48u wide x 75-82u long. A much larger form than West describes.

[1]*Cosmarium impressulum* Elfv. Sullivan Co., May 24, 1931. Monroe Co., June 28, 1929. July 20, 1929.

Cosmarium laeve Rabenh. Vigo Co., June 3, 1930.

[4]*Cosmarium lundellii* Delp. var. *ellipticum* West. Parke Co., June 19, 1929. Grant Co., Sept. 2, 1929. Previously reported from Wales and Scotland.

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[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[2]*Cosmarium lundellii* var. *corruptum* (Turn.) West and G. S. West. Putnam Co., May 23, 1931.

Cosmarium meneghinii Breb. Vigo Co., May, 1930.

[4]*Cosmarium obtusatum* Schmidle. Montgomery Co., Sept. 8, 1929. Vermillion Co., June 6, 1931. Clay Co., June 21, 1930.

[2]*Cosmarium obtusatum* var. *beanlandii* W. and G. S. West. Parke Co., July 5, 1930. Clay Co., June 21, 1930.

Cosmarium ovale Ralfs. Montgomery Co., Sept. 8, 1929. This species was very abundant in this pond from early spring until late fall. Zygospores which according to West are "unknown" were very common throughout the summer.

[1]*Cosmarium ochthodes* Nordst. Montgomery Co., Sept. 8, 1929.

[1]*Cosmarium pachydermum* Lund. Noble Co., Sept. 15, 1929.

[1]*Cosmarium pokornyanum* (Green) W. & G. S. West. Noble Co., Sept. 15, 1929.

[1]*Cosmarium portianum* Archer. Sullivan Co., June 6, 1929, May 24, 1931. Parke Co., June 19, 1929. Montgomery Co., Sept. 8, 1929. Vigo Co., June 3, 1930.

[5]*Cosmarium portianum* var. *major* nov. var. Vigo Co., May, 1930. Greene Co., May 2, 1931. Identical with the species except much larger 38u x 51u, isthmus 17u.

[2]*Cosmarium portianum* var. *nephroidum* Wittr. Vigo Co., Aug. 13, 1930.

[1]*Cosmarium protractum* (Naeg.) De Bary. Montgomery Co., July 14, 1929; Sept. 14, 1929.

[1]*Cosmarium pseudoprotuberans* Kirchn. Vigo Co., June 30, 1930.

[1]*Cosmarium pseudoconnatum* Nordst. Vigo Co., June 6, 1930.

[1]*Cosmarium pseudatlanthoideum* West. Montgomery Co., Sept. 8, 1929.

[1]*Cosmarium pseudopyramidatum* Lund. Vermillion Co., June 6, 1931. Parke Co., July 4, 1930.

[1]*Cosmarium punctulatum* Breb. Montgomery Co., July 3, 1929.

[2]*Cosmarium punctulatum* var. *subpunctulatum* (Nordst.) Borg. Parke Co., June 18, 1929.

[1]*Cosmarium quadratum* Ralfs. Montgomery Co., Sept. 8, 1929.

[1]*Cosmarium quadratulum* (Gay) De Toni. Grant Co., Sept. 2, 1929.

Cosmarium quasillus Lund. Vigo Co., July 7, 1929.

[1]*Cosmarium rectangulare* Grum. Grant Co., Sept. 2, 1929.

[2]*Cosmarium rectangulare* Grum var. *hexagonum* (Elfr.) West & G. S. West. Sullivan Co., June 7, 1930. Kosciusko Co., Sept. 14, 1929.

[1]*Cosmarium reniforme* (Ralfs) Archer. Montgomery Co., Sept. 8, 1929. Vermillion Co., June 6, 1931. Parke Co., June 18, 1931. Grant Co., Sept. 2, 1929.

[2]*Cosmarium reniforme* var. *elevatum* West and G. S. West. Clay Co., May 23, 1931. Noble Co., Sept. 15, 1929.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] **New Varieties.**

[2]*Cosmarium reniforme* var. *compressum* Nordst. Putnam Co., May 23, 1931.

[2]*Cosmarium sexangulare* Lund. forma *minima* Nordst. Vermillion Co., June 6, 1931. Vigo Co., Aug. 13, 1930.

[1]*Cosmarium speciosum* Lund. Clay Co., May 23, 1931.

[2]*Cosmarium speciosum* Lund. var. *simplex* Nordst. Clay Co., May 23, 1931.

[2]*Cosmarium speciosum* var. *rostafinskii* (Gutw.) W. and G. S. West. Parke Co., July 20, 1929.

[1]*Cosmarium subcostatum* Nordst. Parke Co., July 20, 1929.

[2]*Cosmarium subcostatum* var. *minor* West and G. S. West. Vigo Co., May, 1930; June 3, 1930.

Cosmarium subcrenatum Hantz. Grant Co., Sept. 2, 1929. Vigo Co., July 4, 1929.

[1]*Cosmarium supraspeciosum* Wolle. Montgomery Co., Sept. 8, 1929.

[1]*Cosmarium subspeciosum* Nordst. var. *validus* Nordst. Vigo Co., July 30, 1929.

[1]*Cosmarium subcucumis* Schmidle. Putnam Co., May 23, 1931.

[1]*Cosmarium subretusiforme* W. and G. S. West. Vigo Co., July 18, 1930.

[1]*Cosmarium letraophthalmum* Breb. Montgomery Co., Aug. 4, 1929.

[1]*Cosmarium triplicatum* Wolle. Montgomery Co., Sept. 8, 1929.

[2]*Cosmarium turpinii* Breb. var. *eximum* G. S. West. Knox Co., May 23, 1931. Clay Co., May 23, 1931.

[2]*Cosmarium turpinii* Breb. var. *podolicum* Gutw. Sullivan Co., June 8, 1931. Vigo Co., May, 1930; June 26, 1929.

[2]*Cosmarium undulatum* Corda var. *crenulatum* (Naeg) Wittr. Clay Co., June 21, 1930. Length 14-19u x 13-15u width. Much smaller than West's measurements. Cell wall sparsely punctate.

[2]*Cosmarium ungerianum* (Naeg) Be Bary var. *bohemicum* Lutkem. Desm. Bohn. Sullivan Co., May 23, 1931.

[1]*Cosmarium vexatum* West. Vigo Co., June 10, 1931; July 3, 1929.

Desmidium swartzii Agardh. Montgomery Co., Sept. 8, 1929. Sullivan Co., Aug. 24, 1930. Vigo Co., July 12, 1929. Elkhart Co., Sept. 15, 1929.

[2]*Euastrum ansatum* Ralfs. var. *attenuatum* Schmidle. Sullivan Co., Aug. 24, 1930. Schmidle describes this variety as 52u x 120u. The specimens here observed were 54u x 126-130u, otherwise identical with the variety.

[1]*Euastrum bidentatum* Naeg. Parke Co., June 19, 1929. Vigo Co., July 17, 1930.

[1]*Euastrum denticulatum* (Kirchn) Gay. Sullivan Co., July 24, 1930.

[1]*Euastrum dubium* Naeg. Hulman Pond, Vigo Co., July 26, 1930.

[1]*Euastrum insulare* (Wittr.) Roy. Kosciusko Co., Sept. 14, 1929.

[1]*Euastrum oblongum* (Grev.) Ralfs. Putnam Co., May 23, 1931.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

[1]*Euastrum pulchellum* Breb. Sullivan Co., July 24, 1930.

Euastrum verrucossum Ehrenb. Vigo Co., July 12, 1929.

[2]*Euastrum verrucossum* var. *alatum* Wolle. Vigo Co., July 12, 1929. Kosciusko Co., Sept. 14, 1929. Montgomery Co., Sept. 8, 1929. Knox Co., May 2, 1931. Sullivan Co., July 24, 1930.

Hyalotheca dissiliens (Sm.) Breb. Montgomery Co., Sept. 8, 1929. Vigo Co., July 12, 1931. Elkhart Co., Sept. 15, 1929. Sullivan Co., June 21, 1929.

[2]*Hyalotheca dissiliens* forma *tridentula* Nordst. Greene Co., May 4, 1931.

[1]*Micrasterias americana* (Ehrenb.) Ralfs. Knox Co., May 2, 1931. Greene Co., May 4, 1931. Vigo Co., July 12, 1929. Montgomery Co., Sept. 8, 1929.

Micrasterias radiata Hassall. Sullivan Co., June 21, 1929. Vigo Co., June 20, 1929.

Micrasterias truncata (Corda) Breb. Parke Co., June 18, 1929. Vigo Co., May, 1930.

[1]*Penium cucurbitinum* Biss. Parke Co., July 20, 1929.

[1]*Penium libellula* (Focke) Nordst. Vigo Co., July 3, 1929.

Penium margaritaceum (Ehrenb) Breb. Vigo Co., July 24, 1930. Monroe Co., June 28, 1929. Montgomery Co., June 6, 1930.

[1]*Penium minutum* (Ralfs) Cleve. Vigo Co., July 12, 1929.

Penium spirostriolatum Barker. Montgomery Co., June 6, 1930.

[3]*Pleurotaenium ehrenbergii* (Breb) De Bary. Vigo Co., spring, 1929. Elkhart Co., Sept. 15, 1929.

[1]*Pleurotaenium maximum* (Reisch) Lund. Montgomery Co., Sept. 8, 1929. Sullivan Co., Aug. 21, 1930.

[2]*Pleurotaenium maximum* var. *tumidum* Brown. Montgomery Co., Sept. 8, 1929.

[1]*Pleurotaenium trabecula* (Ehrenb) Naeg. Putnam Co., May 23, 1931. Montgomery Co., Aug. 28, 1929. Vigo Co., Aug. 13, 1930.

[2]*Pleurotaenium trabecula* forma *clavata* (Kuetz) West & G. S. West. Vigo Co., Aug. 13, 1930. Kosciusko Co., Sept. 15, 1929.

[2]*Staurastrum anatinum* Cooke and Wills var. *curtum* G. M. Smith. Vigo Co., July 18, 1929.

[2]*Staurastrum anatimum* var. *denticulatum* G. M. Smith. Vigo Co., July 18, 1929.

Staurastrum avicula Breb. Elkhart Co., Sept. 15, 1929.

Staurastrum dilatatum Ehrenb. Vigo Co., May, 1930. Kosciusko Co., Sept. 14, 1929.

Staurastrum fucigerum De Brebisson. Montgomery Co., Sept. 8, 1929.

[2]*Staurastrum gracile* Ralfs. var. *coronulatum* Boldt. Vigo Co., July 18, 1929.

Staurastrum margaritaceum (Ehrenb) Menegh. Vigo Co., June 8, 1930.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

Staurastrum muticum De Breb. Vigo Co., May, 1930.

Staurastrum obiculare Ralfs. Montgomery Co., Sept. 8, 1929. Vigo Co., June 30, 1930. June 18, 1929, Parke Co.

[2]*Staurastrum orbiculare* var. *ralfsii* West and G. S. West. Vigo Co., May 20, 1930.

[1]*Staurastrum polymorphum* Breb. Vigo Co., June 30, 1930.

[2]*Staurastrum paradoxum* Meyen var. *biradiatum* Griffiths. Knox Co., April 25, 1930. Vigo Co., Aug. 4, 1930.

[2]*Staurastrum quadrangulare* De Breb. var. *breviaculeatum* G. M. Smith. Vigo Co., July 17, 1930.

[1]*Staurastrum setigerum* Cleve. Montgomery Co., Sept. 8, 1929.

[2]*Staurastrum setigerum* var. *brevispinum* G. M. Smith. Montgomery Co., Sept. 8, 1929.

[2]*Staurastrum striolatum* (Naeg) Arch. Clay Co., June 21, 1930.

[1]*Staurastrum subgemmulatum* West and G. S. West. Kosciusko Co., Sept. 19, 1929.

[1]*Staurastrum turgescens* De Not. Vigo Co., July 9, 1929.

[1]*Xanthidium antilopaeum* (Breb.) Kuetz. Vigo Co., July 12, 1929.

[2]*Xanthidium antilopaeum* var. *hibridarum* W. and G. S. West. Montgomery Co., July 12, 1929.

[1]*Euglena spirogyra* Ehrenb. Vigo Co., June 8, 1930.

Euglena viridis Ehrenb. Vigo Co., summer, 1930; May 2, 1931.

[1]*Ceratium hirudinella* O. Fr. M. Schrank. Vigo Co., Aug. 14, 1930; Aug. 4, 1930.

[4]*Ceratium hirundinella* var. *carenthianum* Zederb. Vigo Co., Aug. 4, 1930.

[4]*Ceratium hirundinella* var. *piburgense* Zederb. Vigo Co., Aug. 4, 1930.

[4]*Glenodinium oculatum* Stein.

[3]*Codonella cratera* (Leidy) Vorce. Montgomery Co., March 20, 1930.

[1]*Peridinium cinctum* Ehrb. Vigo Co., Aug. 19, 1930.

[4]*Peridinium elpatiewsky* (Ostenf) Lemm. Sullivan Co., July 13, 1930.

[5]*Peridinium laeve* Huitf-Hass var. *wailesii* var. nov. Montgomery Co., March 20, 1930.

[4]*Peridinium lomnicki* Wolosz. Vigo Co., June 13, 1930.

[4]*Peridinium penardi* Lemm. Vigo Co., June 5, 1930; June 13, 1930.

Peridinium quadridens Stein. Vigo Co., Aug. 4, 1930.

[3]*Peridinium* sp. Montgomery Co., March 20, 1930.

[1]*Peridinium willei* Huitf-Haas. Vigo Co., Aug. 19, 1930; June 5, 1930.

Chara fragilis. Clay Co., May 23, 1931.

Chara contraria A. Br. Vigo Co., June 8, 1931.

Nitella species. Vigo Co., May 1, 1931.

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[1] Species—not previously reported from State.

[2] Variety—not previously reported from State.

[3] Genus—not previously reported from State.

[4] Varieties or species—not previously reported from United States.

[5] New Varieties.

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AN ECOLOGICAL STUDY OF THE BALD CYPRESS IN INDIANA

WINONA H. WELCH, DePauw University

The bald cypress, *Taxodium distichum* (L.) Richard, (Fig. 1), grows along the Atlantic coast from southern Delaware to Florida and westward along the Gulf to Texas and north in the Mississippi Valley to southwestern Indiana and southern Illinois. Little Cypress Swamp in the southwestern part of Knox County has the largest acreage of this species in Indiana. This tree also occurs in smaller areas in Posey, Vanderburg, and Warrick counties.

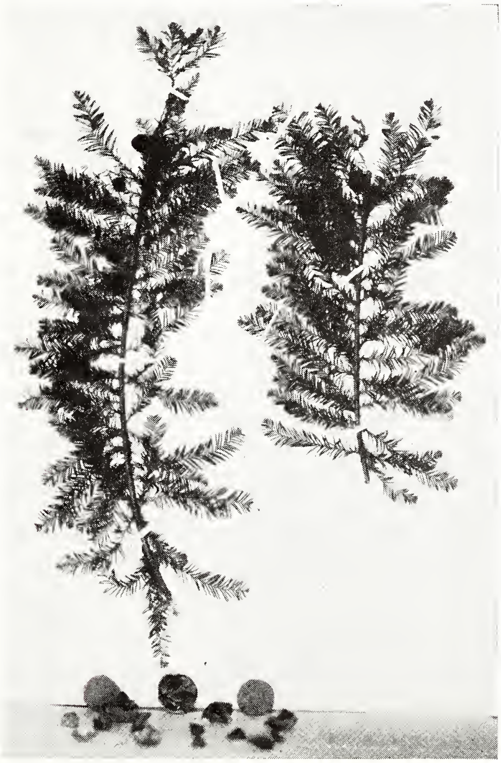

Fig. 1—A portion of two branches of the bald cypress with numerous foliar shoots and a few cones[1].

In June, 1929, the author with a class of Indiana University plant ecology students made several visits, during a period of three consecutive weeks, to the cypress swamps in the above mentioned counties.

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[1] The author is indebted to Dr. Paul Weatherwax for the photographs shown in figures 1, 4, and 5.

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The purpose was to study some of the ecological factors of a cypress swamp. In May, 1931, a DePauw University plant ecology class and the writer visited the Little Cypress Swamp. Although no different data were obtained than in 1929, the drier condition of the area permitted study farther into the swamp.

Discussion of Field Data. Because of the necessity of brevity the detailed data recorded from the field studies are omitted. Although a general discussion of germination and of seedlings is the purpose of this report a few remarks concerning the trees may be of interest.

The largest tree found, (Fig. 2), had a circumference of 45 ft. 4 in. at base and 27 ft. 2 in. four and one-half feet above base.

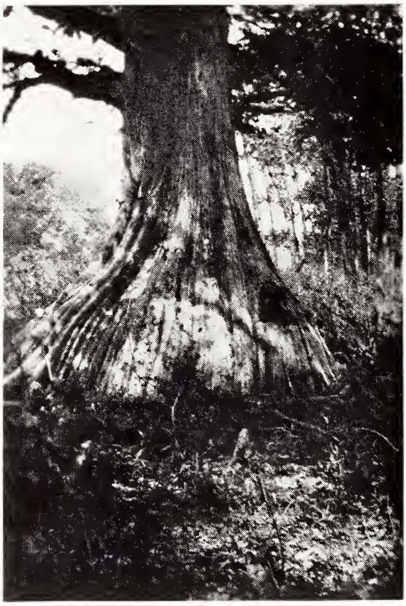

Fig. 2—The largest cypress tree reported in the Little Cypress Swamp. The hole near the base is the result of an examination by lumbermen to determine whether or not the tree would make satisfactory lumber.

The cypress "knees" were numerous and some measured a few inches over four feet in height. (Fig. 3.)

Many large cypress stumps 10 to 15 ft. high were conspicuous during the period of low water. Approximately 400 species of vascular plants were collected in the areas studied, identified, and deposited in the Herbarium of Indiana University.

Hundreds of cypress seedlings a few inches in height were observed in the swamp east of Mt. Vernon. The cotyledons were fully expanded and the first leaves were beginning to appear. Frequently the seedlings were found in clumps. This condition was brought about in various ways: (1) several seeds and cones were washed together in the lower portions of the swamp; (2) cones fell from the tree, were more or less buried in the mud, and several seeds in each cone germinated; and (3) numerous seeds fell from the cones which remained on the trees and germinated in close proximity.

Many seedlings and saplings in Little Cypress Swamp were measured. Although the height varied from four inches to eight feet, the great majority of these small cypresses were less than two feet in height. There was a large gap in size between saplings eight and nine feet high and small trees one foot in circumference. There was an abundance of trees with circumference measurements larger than two feet.

Thousands of cypress seedlings have appeared each year in the swamp lands of southwestern Indiana. Perhaps their destruction has been brought about in one or more of the following ways: (1) almost every spring large portions of this area have been flooded and the logs floating over the seedlings and saplings may have broken the trunks or removed the tops; (2) possibly in winter large pieces of moving ice have broken the young trees; and (3) many acres of this land have been drained and the outer portions of the swamp may have become too dry during certain seasons for the survival of a large number of seedlings. No count of the many broken saplings was made but there was sufficient evidence that the bald cypress seeds germinted and that the seedlings grew under favorable conditions. During recent years the majority of the young cypresses have been destroyed by some factor or combination of factors. The number of young cypress trees in the swamp was noticeably small.

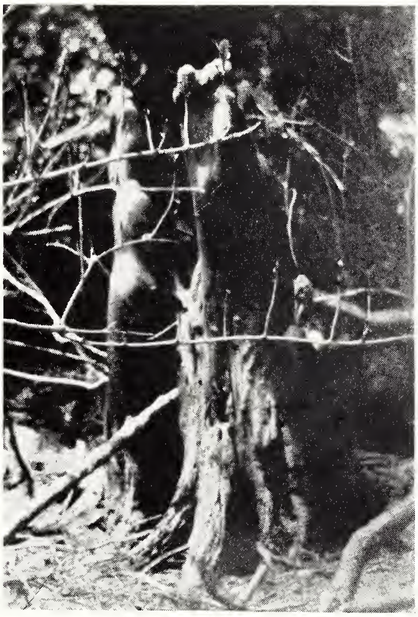

Fig. 3—Two of the tallest "knees" observed by the writer in Little Cypress Swamp.

Discussion of Experimental Methods. The experimental work with cypress seeds and seedlings was done in the greenhouse at Indiana University from September, 1929, to August, 1930. An attempt was made to imitate as many of the swamp conditions as possible. The seeds were selected from cones which were collected in Evansville, Indiana, September 23 and October 21, 1921, by the late Prof. A. J. Bigney. All cones received were in the green stage. The phases of the exprimental work included in this paper concern various methods of seed germination.

Moist Atmosphere. On October 29 two culture dishes were filled with water and each was placed on a large piece of glass. Around one of the vessels was placed cones and seeds from the September collection; around the other, cones and seeds from the October collection were arranged. These were covered with a thin layer of sphagnum. After a bell jar was placed over each preparation, they were set aside on a shelf in the greenhouse. The first seedlings, (Fig. 4), appeared January 3 and in the culture containing seeds collected in October. During the next two months a total of 24 germinations occurred. No seedlings appeared in the culture containing seeds from the September collection until February 17. During the following three weeks there was a total of 37 germinations.

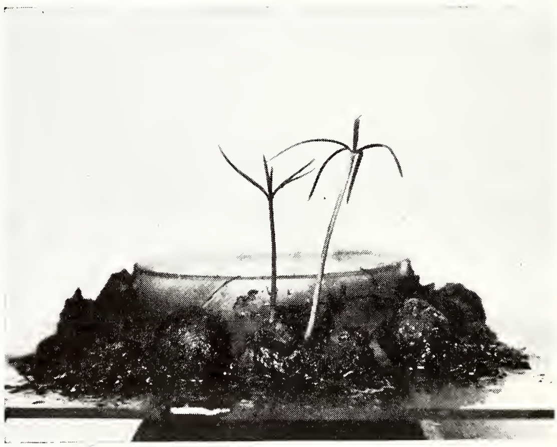

Fig. 4—Two cypress seedlings in cotyledon stage. The seeds germinated in moist atmosphere.

As soon as the hypocotyls were perpendicular, the cotyledons horizontal, the root systems well started, the seedlings were transferred to soil in flower pots. The pots were then placed in crocks which were filled with water so that the seedlings could grow in a water-saturated soil, (Fig. 5). (Daily growth records of all seedlings were made but data concerning growth experiments are not sufficiently complete for publication at this time.)

Water Germination. On October 29 four cones, four seeds attached to sporophylls, and 12 seeds without sporophylls were selected from the September collection. The same procedure was used with the October collection. Each selected group was floated on water in a crock. Three germinations in the September collection occurred about three and one-half months after the experiment was started. Approximately six to eight months after the seeds were floated, nine seeds from the October collection germinated.

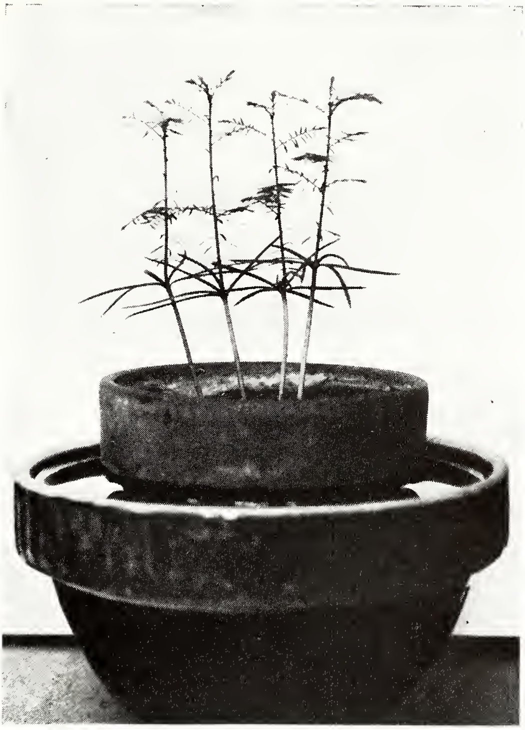

Fig. 5—Illustration of method by which seedlings were grown in water—saturated soil.

As soon as the radicles and cotyledons were well developed, the seedlings were placed in a crock containing a layer of dirt and covered with water. The radicles continued growing in the soil and the seedlings produced foliar shoots beneath the surface of the water.

Sphagnum and Soil. Two hundred seeds were selected from the October collection. On March 20, 100 of these seeds were planted in a box containing ordinary soil. The remaining 100 seeds were planted in a box which contained four alternating layers of sphagnum and dirt. The contents of both boxes were kept well saturated with moisture. The first seedlings appeared in each box about the same date, approximately three or four weeks after planting. Nineteen seeds germinated in the sphagnum and dirt and 38 in the box containing only soil.

Two hundred seeds selected from the September collection were treated in the same manner. The first seed germinated in the mixture of sphagnum and dirt about one and one-half months after planting, and in dirt alone about one month after planting. There was a total of 22 seedlings in dirt and sphagnum and 37 in the soil. From these data based upon 400 seeds the number of germinations in the soil about doubled that in the mixture of soil and sphagnum.

Depth of Planting. Thirty-six seeds were selected from each collection and 12 of each were planted two centimeters beneath the soil surface, 12 of each four centimeters beneath the surface, and 12 of each at a depth of eight centimeters. The pots were placed in crocks of water so that the soil could be kept uniformly moist. Although the total number of germinations was small, three strong seedlings developed from the seeds planted at a depth of eight centimeters.

Flooding Experiment. One seedling was selected which was growing nicely in a flower pot. On February 19 this pot and seedling were placed in a battery jar and the plant covered with two inches of water. Measurements of the foliar shoots were made and the needles counted. On April 3, the measurements and the count were repeated and it was found that no change had occurred. At this time the depth of water was decreased so that the tips of the foliar shoots extended above the water. The water was maintained at a constant level and by May 12 the foliar shoots had increased their length 2.2 and 2.5 cms. and had produced 35 and 34 new needles, respectively.

This experiment was continued by moving 10 potted seedlings to an outdoor pool. During the earlier part of the experiment the tips of the foliar shoots were exposed above the surface of the water and the amount of growth was recorded weekly. After several weeks of rapid growth the pots were lowered so that the plants were beneath the surface of the water. Measurements were made weekly but no growth was observed. Thus it seemed that the cypresses could live under water for several weeks but during that time no measurable growth occurred.

Transplanted Seedlings. To determine the possibility of this species growing farther north in Indiana several seedlings have been transplanted from the swamps and from the Indiana University greenhouse to various more northern habitats. The seedlings in all places, including the locality farthest north (85 miles south of Chicago), have been growing very nicely.

On the east side of the Indiana University greenhouse there is a bed of 60 to 75 cypress saplings. They have grown from seeds germinated in the experiments previously discussed, between December, 1929, and August, 1930. At this time the average height of these trees is between two and one-half and three feet. The largest primary stem measures[1] 25 mms. (one inch, caliper measure) in diameter four inches above the ground. The average diameter by caliper measurements, just above and just below the cotyledon scars, at the time of transplanting was approximately two and one-half millimeters. This increase in circumference has taken place during the last year (summer of 1930 to that of 1931).

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[1] This fact was received in a letter from Prof. D. M. Mottier, Nov. 2, 1931.

Dunn Meadow Cypress Trees. On August 31, 1931, a survey was made by the writer concerning the number of cypress trees in Dunn Meadow along Jordan River on the Indiana University campus, the number of "knees", and the general moisture conditions of the habitat. This group consists of 12 trees which range in circumference, at the base of tree, from three feet and one inch to five feet and nine inches. When measured three feet above the ground the range is from one foot and eleven inches to four feet and five inches. A brief summary of the investigation follows. (1) Six of the 12 cypress trees had "knees." (2) Forty-one "knees" were counted. Thirty-nine of these were found on roots of the trees growing in the low moist ground and two were on trees in drier soil. (3) "Knees" varied in height from one and one-half inches to five inches. (4) There seemed to be no correlation between the size of the tree and the production of "knees" nor between the size of tree and the number of "knees" produced. (5) There is no record of cone production by these specific trees.

SUMMARY

1. Seeds of *Taxodium distichum* collected in southern Indiana in September and October germinated in approximately three months.
2. Seeds germinated in a moist chamber, in water, in soil alone, and in a mixture of soil and sphagnum.
3. Healthy and strong seedlings developed from seeds planted at a depth of eight centimeters.
4. As the length of time between the collecting of the seeds and the planting, (rest period), increased, the period of time required for germination became less.
5. In consideration of the number of seeds planted the percentage of germination was low.
6. Approximately the same number of germinations resulted from the seeds collected in September as from those gathered in October.
7. Apparently no growth occurred while seedlings were submerged but upon emergence, growth was resumed. The seedlings lived under water but made no noticeable growth unless the growing points of the shoots were above the water.
8. Although the bald cypress in Indiana does not grow naturally north of Knox county, this species has been transplanted successfully to northern portions of the state (85 miles south of Chicago). (Two large trees are growing in Greencastle.)
9. Based upon numerous observations made in the swamps and in Dunn Meadow, Indiana University campus, there seems to be no correlation between the size of the tree and the production of "knees" or the size of the tree and the number of "knees" produced. The "knees" did not seem to be characteristic of the younger and the smaller trees.
10. The seedlings under observation had from four to eight cotyledons. Four and eight were rare, five and seven were frequent, and six was the most common.

ORGANIC COMPOUNDS OF SELENIUM, IV

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HOMO- and HETEROCYCLIC DISELENIDES

Introduction. This paper is the fourth of a series having as its object the furthering of research work in the chemistry of organic selenium compounds. It presents a complete list of the known homo- and heterocyclic diselenides, a résumé of the methods of preparation for each compound, and a complete bibliography for each compound.

Discussion. A consideration of the body of this paper will show that it consists of three parts: general methods for the preparation of diselenides, a classified list of diselenides, and a bibliography. An examination of the methods of preparation will show that to each method is assigned a number, and that with each method are listed reference numbers which correspond to the pertinent reference in the bibliography. In this way, by a consideration of the table of methods, one can ascertain by the reference numbers something of the extent to which that method has been used and can easily obtain detailed information regarding the method by consulting these references. In the same manner, any compound in the list of diselenides will show by number the methods by which that compound has been prepared, and also by number, the references in which that compound is mentioned.

A more detailed consideration of the general methods for the preparation of diselenides will show that in many cases the first equation is not balanced, and is in fact only a listing of reagents and final products. When this is the case, the equation is ended by a plus sign to indicate that it is incomplete. Following this, frequently, will be found balanced equations which endeavor to show the probable mechanism of the reaction. Regarding these equations, it must be remembered that they are often based upon properties reported during the early work in this field, and consequently are in no sense authoritative. Additional information will possibly necessitate the revision of several of these equations. This is well illustrated by preparation method No. 9. In this case the first equation is a list of starting materials and resultant products, while the following equations are merely an effort to explain the presence of these products. Additional information regarding the properties of the compound $(HR)_2SeX_2$ would no doubt necessitate some modification in this instance.

A consideration of the chemistry of the preparation of diselenides will show that the actual preparation of the diselenide is based upon fewer reactions than the 26 listed. This can well be illustrated as follows: any one of several starting materials can be converted into

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organic selenols, which can in turn be oxidized to organic diselenides. From this it can be seen that the methods of preparation listed have been classified on the basis of starting material, rather than on the basis of the reaction immediately concerned in the preparation of the diselenide. This is necessary because of the lack of definite information regarding the mechanism of these reactions.

Special notice should be called to methods No. 25 and No. 26. Method No. 25 includes all methods based on chemistry not affecting the selenium atom in the molecules concerned. Here, then, are listed cases of reduction, dehydration, ester formation, and other reactions of like nature. Method No. 26 is actually not a method of preparation, but merely a remark designed to indicate that a diselenide was prepared and reported under an erroneous name.

Nomenclature. In many cases the nomenclature used by the original authors has been modified in order to obtain a uniform system. In the case of the heterocyclic compounds, common names have been replaced by systematic names. In the homocyclic compounds, the name "*propyl-gamma-diselenido-diphthalamate,*" (2-$CONH_2$-3-$COOC_3H_7$-$C_6H_3)_2Se_2$, was changed to "*di(3-propyl ester of 2-3-phthalamic acid) diselenide*". This change was considered desirable since the original name did not indicate the position of the groups and also because it was desired to name all the compounds with the selenium atom as a reference point. Other changes, which have been made for similar reasons, will be noted in the tables. The abbreviations which have been used in the tables are those recommended by Chemical Abstracts, and have been previously (7) described.

Properties. Selenium reacts readily with magnesium alkyl haloids and the complexes formed yield on treatment: (a) with dilute acids, selenophenols and diselenides; (b) with acid chlorides or anhydrides, esters of the series of selenol acids, (R-CO-SeH); and (c) with alkyl iodides, mixed selenides. The compounds formed are strictly analogous with those resulting from the action of sulphur on magnesium alkyl haloids (38).

The usual structure of diselenides is of the type (R-Se-Se-R). However a compound of the type ($R_2{=}Se{=}Se$) called selen-selenide because of the similarity to the selenoxide, ($R_2{=}Se{=}O$), has been prepared. This compound was *B-dinaphthyl-selen-selenide,* (B-$(C_{10}H_7)_2{=}Se{=}Se$), and is an isomer of *B-dinaphthyl diselenide,* (B-$(C_{10}H_7)_2Se_2$). When (B-$(C_{10}H_7)_2SO_2$) is heated with metallic selenium, the selen-selenide is formed (28). This has a different melting point from the diselenide and also different physical properties. The selen-selenide reacted with potassium dichromate to form *(di-B-naphthyl) selenoxide,* (B-$(C_{10}H_7)_2{=}Se{=}O$), while the diselenide was unaffected under the same conditions. The selen-selenide reacted with a reducing agent to form *B-dinaphthyl selenide,* (B-$(C_{10}H_7)_2Se$), while the diselenide reduced to *B-naphthyl-selenol,* (B-$(C_{10}H_7)SeH$).

Moderate heating of diselenides causes one atom of selenium to drop out of the compound resulting in the formation of the corresponding selenide. The properties of selenides have been previously reported (7).

Intense heating of some diselenides, such as *di-(2-4-dinitrophenyl-) diselenide*, $(2\text{-}4\text{-}(NO_2)_2{=}C_6H_3\text{-})_2Se_2$, results in detonation.

Several diselenides have been oxidized by nitric acid and the product formed was the corresponding seleninic acid (29-31-33-34). Concentrated nitric acid apparently does not cause the formation of hexavalent selenium. An alkaline solution of potassium permanganate also gives rise to the seleninic acid (31). An alkaline solution of potassium permanganate has been used with success in the oxidation of diselenides (24-25) to the corresponding selenonic acids. Thirty per cent hydrogen peroxide in glacial acetic acid (30) and also moist chlorine (36) have been used to oxidize diselenides to selenonic acids, $(R\text{-}SeO_3H)$.

Several diselenides also have been reduced. The product formed is in each case the corresponding selenol. Zinc dust with HCl (1) and zinc dust with acetic acid (5) were used.

Diphenyl diselenide and *di(1-phenyl-3-methyl-4-benzoyl-pyrro-(a)-monazolyl-5) diselenide* form the tetrabromide upon the addition of bromine in chloroform solution (30).

It is interesting to note that the color of every diselenide mentioned in the literature was yellow. Diselenides are purified in most cases by crystallization from either alcohol or ether.

THE PREPARATION OF HOMO- AND HETEROCYCLIC DISELENIDES

GENERAL METHODS

(R = homocyclic)

Method No.	*Equations*	*Ref. Nos.*
1.	$\mathrm{Se + R_2Se + heat = R_2Se_2.}$	26, 20
2.	$\mathrm{Se + RMgX + Et_2O; + H_2O + HCl = R_2Se +}$ $\mathrm{R_2Se_2 + RSeH +}$ $\mathrm{Se + RMgX = RSeMgX; + HCl = RSeH + MgXCl.}$ $\mathrm{2Se + 2RMgX = R_2Se + Se(MgX)_2.}$ $\mathrm{3Se + 2RMgX = R_2Se_2 + Se(MgX)_2.}$ (X = Br)	4, 38, 39
3.	$\mathrm{Se + M_2Se + RX + heat = R_2Se_2 + MX +}$ $\mathrm{M_2Se + 2RX = R_2Se + 2MX.}$ $\mathrm{R_2Se + Se + heat = R_2Se_2.}$ (M = Na; X = Cl;)	2, 5, 6
4.	$\mathrm{Se + R_2SO_2 = R_2Se_2 +}$ $\mathrm{R_2SO_2 + 2Se = R_2Se_2 + SO_2.}$	20, 28
5.	$\mathrm{Se_2X_2 + RH = R_2Se + R_2Se_2 +}$ $\mathrm{Se_2X_2 + 2RH = R_2Se_2 + 2HX.}$ (R = heterocyclic)	18
6.	$\mathrm{Se_2X_2 + RMgX' = R_2Se + R_2Se_2 +}$ $\mathrm{Se_2X_2 + 2RMgX' = R_2Se_2 + 2MgXX'.}$ (X = Cl, Br; X′ = Br;)	32, 37
7.	$\mathrm{Se_2X_2 + RH + Al_2X_6' + CS_2 = R_2Se + R_2Se_2 + RX +}$ $\mathrm{Se_2X_2 + 2RH + (Al_2X_6') = R_2Se_2 + 2HX.}$ $\mathrm{Se_2X_2 + RH + (Al_2X_6') = RX + HX + 2Se.}$ $\mathrm{R_2Se_2 + heat = R_2Se + Se.}$ (X = Br; X′ = Br;)	27
8.	$\mathrm{SeX_4 + RH + (Al_2X_6) = R_2Se_2 + R_2SeX_2 + HX + RX +}$ (X = Cl)	3, 8, 19
9.	$\mathrm{SeO_2 + H_2R + (Al_2X_6) + heat = (HR)_2Se_2 + (HR)_2Se +}$ $\mathrm{(HR)_2SeX_2 + (XR)_2Se + HX +}$ $\mathrm{SeO_2 + 2H_2R + (Al_2X_6) = (HR)_2SeO + H_2O.}$ $\mathrm{(HR)_2SeO + 2HX + (Al_2X_6) = (HR)_2SeX_2 + H_2O.}$ $\mathrm{2H_2O + Al_2X_6 = 2Al(OH)X_2 + 2HX.}$ $\mathrm{2(HR)_2SeX_2 + heat = (HR)_2Se + (XR)_2Se + 2XH.}$ $\mathrm{(HR)_2Se + Se + heat = (HR)_2Se_2.}$ (X = Cl;)	29
10.	$\mathrm{K_2Se_2O_3 + 2RX = R_2Se_2 + 2KX +}$ (X = Br, Cl;)	40
11.	$\mathrm{M_2Se + RNNX = R_2Se + R_2Se_2 + MX + N_2 +}$ $\mathrm{M_2Se + 2RNNX + HX + heat = R_2Se + 2MX + 2N_2.}$ $\mathrm{M_2Se_2 + 2RNNX = R_2Se_2 + 2N_2 + 2MX.}$ (M = H, Na, K; X = Cl;) ($\mathrm{M_2Se_2}$ is a common impurity in $\mathrm{M_2Se}$.)	24, 25

Method No.	*Equations*	*Ref. Nos.*
12.	$\mathrm{MSeCN + M'OH + RNNX = RSeCN + MX + N_2 +}$ $\mathrm{R_2Se + R_2Se_2 +}$ $\mathrm{MSeCN + RNNX = RSeCN + MX + N_2.}$ $\mathrm{RSeCN + M'OH = RSeH + M'OCN.}$ $\mathrm{2RSeH + O = R_2Se_2 + H_2O.}$ $\mathrm{2RSeCN = R_2Se + Se + (CN)_2.}$ ($\mathrm{O = CCl_3NO_2, H_2O_2}$, Br water, or by electrolysis in alkaline solution)	1, 9, 10 13, 15 16, 17 22, 28 31
13.	$\mathrm{MSeCN + RNNX + HX' = RSeCN + MX + N_2 + R_2Se_2 +}$ $\mathrm{MSeCN + RNNX = RSeCN + MX + N_2.}$ $\mathrm{RSeCN + H_2O + (HX') = RSeH + HOCN.}$ $\mathrm{2RSeH + O = R_2Se_2 + H_2O.}$ ($\mathrm{M = K; X = Cl; X' = NO_3; O =}$ air, $\mathrm{HX'}$)	9, 10 23
14.	$\mathrm{MSeCN + XRCOONa + Cu + H_2O = MX + HOCN +}$ $\mathrm{MCN + Cu_2Se + (RCOONa)_2Se_2 +}$ $\mathrm{XRCOONa + (Cu) + MSeCN = NaOOCRSeCN + MX.}$ $\mathrm{NaOOCRSeCN + H_2O = NaOOCRSeH + HOCN.}$ $\mathrm{2NaOOCRSeH + O = (NaOOCR)_2Se_2 + H_2O.}$ $\mathrm{2Cu + MSeCN = Cu_2Se + MCN.}$ ($\mathrm{M = K; X = Br; O =}$ air;)	35
15.	$\mathrm{2RSeH + O = R_2Se_2 + H_2O.}$ (O = air, $\mathrm{H_2O_2}$;)	1, 3, 14 17, 28, 30 38, 39
16.	$\mathrm{R_2SO_2 + Se = R_2Se_2 + SO_2 +}$ $\mathrm{R_2SO_2 + Se = R_2Se + SO_2.}$ $\mathrm{R_2Se + Se = R_2Se_2.}$	7, 21
17.	$\mathrm{2RSeOOH + 3H_2 = R_2Se_2 + 4H_2O.}$ ($\mathrm{H = NaHSO_3}$;)	34
18.	$\mathrm{H_2N\text{-}R\text{-}SeH + HCOOH; + R'X; + MOH = (R'HN\text{-}RSe\text{-})_2 +}$ $\mathrm{\underbrace{N\text{-}R\text{-}Se\text{-}CH} + R'X\underbrace{N\text{-}R\text{-}Se\text{-}CH} + R'HN\text{-}R\text{-}SeH +}$ $\mathrm{H_2N\text{-}R\text{-}SeH + HCOOH = \underbrace{N\text{-}R\text{-}Se\text{-}CH} + 2H_2O;}$ $\mathrm{+ R'X = R'X\underbrace{N\text{-}R\text{-}Se\text{-}CH}; + H_2O + MOH = MX +}$ $\mathrm{HCOOH + R'HN\text{-}R\text{-}SeH; + O = (R'HN\text{-}RSe\text{-})_2 + H_2O.}$ ($\mathrm{R = C_6H_4; R' = CH_3; X = I; M = NH_4; O =}$ air;)	12
19.	$\mathrm{H_2N\text{-}R\text{-}SeH + R'COOH; + R''X; + MOH = (R'\text{-}CO\text{-}NR''\text{-}RSe\text{-})_2}$ $\mathrm{+ \underbrace{N\text{-}R\text{-}Se\text{-}CR'} + R''X\underbrace{N\text{-}R\text{-}Se\text{-}CR'} + HSeR\text{-}NR''\text{-}CO\text{-}R' +}$ $\mathrm{H_2N\text{-}R\text{-}SeH + R'COOH = \underbrace{N\text{-}R\text{-}Se\text{-}CR'} + 2H_2O; +}$ $\mathrm{R''X = R''X\underbrace{N\text{-}R\text{-}Se\text{-}CR}; + MOH = HSe\text{-}R\text{-}NR''\text{-}CO\text{-}R' +}$ $\mathrm{MX; + O = (R'\text{-}CO\text{-}NR''\text{-}RSe\text{-})_2 + H_2O.}$ ($\mathrm{R = C_6H_4; R' = H, C_6H_5, CH_3; R'' = CH_3;}$ $\mathrm{M = Na, H; X = I; O = K_3Fe(CN)_6, I;}$)	12

Method No. *Equations* *Ref. Nos.*

20. $H_2N-R-SeH + (CH_3CO)_2O; + R'X; + MOH =$ 11

$(CH_3-CO-NR'-R-Se-)_2 + \underbrace{N-R-Se-CCH_3}_{} + CH_3CHO +$

$R'X\underbrace{N-R-Se-C}_{}CH_3 + HSe-R-NR'-CO-CH_3 +.$

$H_2N-R-SeH + (CH_3CO)_2O = \underbrace{N-R-Se-C}_{}-CH_3 +$

$CH_3CHO + H_2O; + R'X = R'X\underbrace{N-R-Se-C}_{}-CH_3; + MOH =$

$MX + HSe-R-NR'-CO-CH_3; + O = (CH_3-CO-NR'-R-Se-)_2 + H_2O.$

($R = C_6H_4$; $R' = CH_3$; $M = Na$; $X = I$; $O =$ air;)

21. $\underline{Se-R-CO-CO} + MOH; + HX = (HOOC-CO-R-Se-)_2 +$ 23

$HSe-R-CO-COOM +$

$\underline{Se-R-CO-CO} + MOH = HSe-R-CO-COOM.$

$HSe-R-CO-COOM + O = (MOOC-CO-R-Se-)_2 + H_2O.$

$(MOOC-CO-R-Se-)_2 + 2HX = (HOOC-CO-R-Se-)_2 + 2MX.$

($R = C_6H_4$; $M = Na, CH_3, C_2H_5$; $X = Cl$;

$O =$ air; when $M =$ alkyl, the final step was omitted.)

22. $\underline{Se-R-COH=CH} + HNO_2; + (NaOH) + H_2O =$ 23

$(COOH-R-Se-)_2 + HOCN + \underline{Se-R-CO-C}=NOH+$

$HOOC-R-SeH +$

$\underline{Se-R-COH=CH} + O=NOH =$

$\underline{Se-R-CO-C}=N-OH + H_2O; + H_2O + (NaOH) =$

$HOOC-R-SeH + HOCN; + O = (COOH-R-Se-)_2 + H_2O.$

($O =$ air)

23. $\underline{R-CO-CO-Se} + R'(NH_2)_2 = (\underline{COH=N-R'-N=C}-R-Se-)_2 +$ 23

$\underline{COH=N-R'-N=C}-R-SeH +$

$\underline{R-CO-CO-Se} + R'(NH_2)_2 = \underline{COH=N-R'-N=C}-R-SeH + H_2O.$

$2\underline{COH=N-R'-N=C}-R-SeH + O = (\underline{COH=N-R'-N=C}-R-Se-)_2$

$+ H_2O.$

($R' =$ *o*-substituted benzene or 1-2
substituted naphthalene; $O =$ air;)

24. $\underline{RN-CH_3N-CH_3C=C(N(CH_3)_2)-C}=Se + I_2 =$ 30

$(\underline{RN-CH_3IN=CH_3C-C(N(CH_3)_2)=C}-SeC-)_2.$

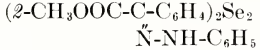
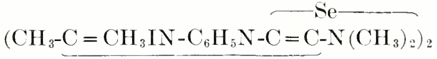
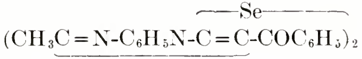
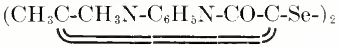
25. All methods not affecting the selenium atom. 17, 23
24, 25
33

26. Methods of preparing diselenides which are erroneously reported in the literature as other compounds. 8

LIST OF HOMO- AND HETEROCYCLIC DISELENIDES

Diselenides	*Formulas*	*M.P.* °C	*Methods of Prep.*	*Ref. Nos.*
Diphenyl-	$(C_6H_5)_2Se_2$	62	1, 2, 7	8, 9
		62.5	6, 8, 9	17, 20
		60	12, 15	21, 19
		63	16	26, 29
		62.5		27, 32
		65		38, 39
				37
Di-*4*-bromophenyl-	$(4\text{-}Br\text{-}C_6H_4)_2Se_2$	107-108	12	3, 9
		106-107	15	10, 38
Di-*4*-chlorophenyl-	$(4\text{-}Cl\text{-}C_6H_4)_2Se_2$	85-86	12, 13	9, 10
		85-87	15	31, 38
		89		
Di-*4*-hydroxyphenyl-	$(4\text{-}OH\text{-}C_6H_4)_2Se_2$	134	12	17
Di-*2*-nitrophenyl-	$(2\text{-}NO_2\text{-}C_6H_4)_2Se_2$	206		
		209	3, 12	1, 5
			15	6, 14
Di-*3*-nitrophenyl-	$(3\text{-}NO_2\text{-}C_6H_4)_2Se_2$	83	17	33, 34
Di-*4*-nitrophenyl-	$(4\text{-}NO_2\text{-}C_6H_4)_2Se_2$	. .	15	14
Di-*4*-acetoxyphenyl-	$(4\text{-}CH_3OC\text{-}C_6H_4)_2Se_2$	90.5	12	17
Di-*2*-carboxyphenyl-	$(2\text{-}HOOC\text{-}C_6H_4)_2Se_2$	296-297	11, 14	23, 24
		294-295	22	25, 35
Di-*4*-carboxyphenyl-	$(4\text{-}HOOC\text{-}C_6H_4)_2Se_2$	314-315	11	16, 25
		297	12	
Di-methyl ester of di-*2*-carboxyphenyl-	$(2\text{-}CH_3OOC\text{-}C_6H_4)_2Se_2$	M-2HCl-ide =74-75	12 25	22, 25

Diselenides	*Formulas*	*M. P. °C*	*Methods of Prep.*	*Ref. Nos.*
Di-ethyl ester of di-*2*-carboxyphenyl-	$(2\text{-}C_2H_5OOC\text{-}C_6H_4)_2Se_2$	129-130	25	25
Di-amide of di-*2*-carboxyphenyl-	$(2\text{-}H_2NOC\text{-}C_6H_4)_2Se_2$	265-266	25	24
Di-*4*-ethoxyphenyl-	$(4\text{-}C_2H_5O\text{-}C_6H_4)_2Se_2$	65	2, 15	4, 38
Di-*4*-tolyl-	$(4\text{-}CH_3\text{-}C_6H_4)_2Se_2$	47	12, 15	9, 38
Di-*2*-aminophenyl-	$(2\text{-}H_2N\text{-}C_6H_4)_2Se_2$	81	15	1
Di-*3*-aminophenyl-	$(3\text{-}H_2N\text{-}C_6H_4)_2Se_2$	M-2HCl-ide	6	32, 33
		=291-292	25	
Di-*3*-acetylaminophenyl-	$(3\text{-}CH_3CONH\text{-}C_6H_4)_2Se_2$	185-6	25	33
Di-*2*-methylaminophenyl-	$(2\text{-}CH_3NH\text{-}C_6H_4)_2Se_2$	89	18	12
Di-*2*-formylaminophenyl-	$(2\text{-}CHONH\text{-}C_6H_4)_2Se_2$	174	19	12
Di-*2*-formylmethyl-aminophenyl-	$(2\text{-}CHONCH_3\text{-}C_6H_4)_2Se_2$	104	19	12
Di-*2*-benzoylmethyl-aminophenyl-	$(2\text{-}C_6H_5CONCH_3\text{-}C_6H_4)_2Se_2$	170	19	12
Di-*2*-acetylmethyl-aminophenyl-	$(2\text{-}CH_3CONCH_3\text{-}C_6H_4)_2Se_2$	141	20	11
Di-acid chloride of di-*2*-carboxyphenyl-	$(2\text{-}ClOC\text{-}C_6H_4)_2Se_2$	173-174	25	25
Di-HCl-ide of di-acid chloride of di-*2*-carboxyphenyl-	$(2\text{-}ClOC\text{-}C_6H_4)_2Se_2\text{-}2HCl$	65-66	25	22, 25
Di-*2*-(glyoxalic acid) phenyl-	$(2\text{-}HOOC\text{-}CO\text{-}C_6H_4)_2Se_2$	. .	21	23
Di-methyl ester of ″-	$(2\text{-}CH_3OOC\text{-}CO\text{-}C_6H_4)_2Se$	157-8	21	23
Di-ethyl ester of ″-	$(2\text{-}C_2H_5OOC\text{-}CO\text{-}C_6H_4)_2Se_2$	125-6	21	23
Di-propyl ester of ″-	$(2\text{-}C_3H_7OOC\text{-}CO\text{-}C_6H_4)_2Se_2$	111-2	21	23

Di-phenyl hydrazone of di-methyl ester of di-*2*-(glyoxalic acid) phenyl-	 $(2\text{-}CH_3OOC\text{-}\underset{N\text{-}NH\text{-}C_6H_5}{\underset{\Vert}{C}}\text{-}C_6H_4)_2Se_2$	72-3	25	23
Di-*2*-*4*-dinitrophenyl-	$(2\text{-}4\text{-}(NO_2)_2\text{-}C_6H_3)_2Se_2$	264-5	10, 12	15, 19
Di-*2*-nitro-*4*-chloro-phenyl-	$(2\text{-}NO_2\text{-}4\text{-}Cl\text{-}C_6H_3)_2Se_2$	127	13	10
Di-*2*-nitro-*4*-tolyl-	$(2\text{-}NO_2\text{-}4\text{-}CH_3\text{-}C_6H_3)_2Se_2$	69	13	10
Di-*3*-nitro-*4*-tolyl-	$(3\text{-}NO_2\text{-}4\text{-}CH_3\text{-}C_6H_3)_2Se_2$	150	13	10
Di-*3*-hydroxy-*6*-methylphenyl-	$(3\text{-}OH\text{-}6\text{-}CH_3\text{-}C_6H_3)_2Se_2$	47	2	39
Di-(*3*-propyl ester of *2*-*3*-phthalamic acid)-	$(2\text{-}CONH_2\text{-}3\text{-}COOC_3H_7\text{-}C_6H_3)_2Se_2$	84	12	13
Di-(*2*-ethyl ester of *3*-*2*-phthalamic acid)-	$(2\text{-}COOC_2H_5\text{-}3\text{-}CONH_2\text{-}C_6H_3)_2Se_2$	118-9	12	13
Di-*1*-naphthyl-	$(1\text{-}C_{10}H_7)_2Se_2$	87-8	2	38
Di-*2*-naphthyl-	$(2\text{-}C_{10}H_7)_2Se_2$	126-7	12	28
Di-(*2*-hydroxy-*3*-*o*-Quinoxalyl) phenyl-	$(HO\underline{C=N\text{-}C_6H_4\text{-}N=C}\text{-}C_6H_4\text{-}Se\text{-})_2$	320-5	23	23
Di-(*2*-hydroxy-*3*-*o*-naphthoquinoxalyl) phenyl-	$(HO\underline{C=N\text{-}C_{10}H_6\text{-}N=C}\text{-}C_6H_4\text{-}Se\text{-})_2$	352-5	23	23
Di-*alpha*-anthraquinone	$A(C_{14}H_7O_2)_2Se_2$	..	3	2
Di(*1*-phenyl-*2*-methiodo-*3*-methyl-*4*-dimethylamino-pyrro-(*a*)-monazolyl-*5*-)-	 $(CH_3\text{-}\underline{C=CH_3IN\text{-}C_6H_5N\text{-}}\overbrace{\underline{C=C}\text{-}N(CH_3)_2)_2}^{Se}$	190	24	30
Di-(*1*-phenyl-*3*-methyl-*4*-benzoyl-pyrro-(*a*)-monazolyl-*5*-)-	 $(CH_3\underline{C=N\text{-}C_6H_5N\text{-}}\overbrace{\underline{C=C}\text{-}COC_6H_5)_2}^{Se}$	141	15	30
Di-(*1*-phenyl-*2*-*3*-dimethyl-pyrro-(*a*)-monazolonyl-*4*-)-	 $(CH_3\underline{\underline{C\text{-}CH_3N\text{-}C_6H_5N\text{-}CO\text{-}C}}\text{-}Se\text{-})_2$	215-6	5	18

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ORGANIC COMPOUNDS OF SELENIUM, V[1]

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Cyclic Selenols

Introduction. The purpose of this paper is to present a complete list of the cyclic selenols that have been reported in the literature prior to 1931. A complete bibilography and the known methods of preparation are listed (See Tables II and III) for each compound. The equations listed (See Table I) under the methods of preparations are expressed in general terms. In all the equations in this article "R" represents a univalent homocyclic radical unless otherwise stated. The selenols, which are analogues of alcohols and phenols, are represented by the formula R-SeH. Aliphatic selenols, which have been previously described (6), therefore correspond to aliphatic alcohols and mercaptans while the cyclic selenols correspond to phenols and thiols. Mention of 23 cyclic selenols was found in the literature.

Properties. The cyclic selenols like the mercaptans are characterized by a very disagreeable odor. Most of them are colorless compounds. Some have been reported as having a slight yellow color (30). This may be due to a trace of impurity, such as the diselenide, which is formed by oxidation of the selenol. Long exposure to air produces this discolorization. The selenols are generally solids at ordinary temperatures, and become liquids above 100° C. with a specific gravity approximately twice that of water. They are soluble in both alcohol and ether and may be crystallized from these solvents. They are only slightly soluble in water but in an alkaline solution soluble compounds are formed. Phenyl selenol has been separated from an acid solution by steam distillation (17). With soluble salts of the heavy metals the selenols form insoluble seleno mercaptides or selenolates.[2]

$RSeH + MX = RSeM + HX.$

(M = Na, K, Hg, Zn, Pb, Ag, or Cu; X = halide or hydroxide.)

With alkyl halides the soluble selenolates react to form selenides.
$RSeM + RX = RSeR + MX.$

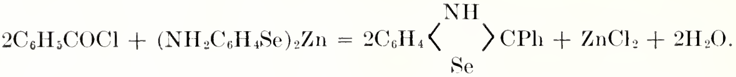
The zinc salt of *2*-aminophenyl selenol or zinc *2*-aminophenyl selenolate in the presence of ethyl acetate reacts with benzoyl chloride to produce *1*-phenylbenzoselenazole (1).

---

[1] This paper is the fifth in a series which will ultimately present a classification of the prepared selenium organic compounds and a resume of the chemistry and literature pertaining to them.

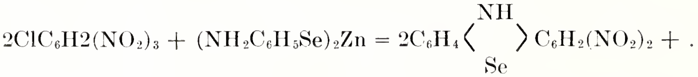
[2] Named after the term alcoholate. This nomenclature is preferred to seleno mercaptide because the term seleno should refer only to a divalent selenium, both valences of which are directed to the same carbon atom.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."



$$2C_6H_5COCl + (NH_2C_6H_4Se)_2Zn = 2C_6H_4\left\langle\begin{matrix}NH\\ \\Se\end{matrix}\right\rangle CPh + ZnCl_2 + 2H_2O.$$

With picryl chloride the zinc salt of *o*-aminophenyl selenol undergoes condensations with the formation of *3-5*-dinitroselenazine.



$$2ClC_6H2(NO_2)_3 + (NH_2C_6H_5Se)_2Zn = 2C_6H_4\left\langle\begin{matrix}NH\\ \\Se\end{matrix}\right\rangle C_6H_2(NO_2)_2 + .$$

The selenols are very easily oxidized by contact with air or other mild oxidizing agents to the coresponding diselenides.

$2RSeH + O = R\text{-}Se\text{-}Se\text{-}R + H_2O.$

Stronger oxidizing agents[3] oxidize either the selenol or the diselenide to the seleninic acid. Still stronger oxidation[4] will bring about the formation of the corresponding selenonic acid. In the oxidation of the selenol, the diselenide and the seleninic acid may be formed as intermediate compounds with the selenonic acid as the final product.

$RSeH + O_2 = RSeOOH.$

$R\text{-}Se\text{-}Se\text{-}R + 3(O) + H_2O = 2RSeOOH.$

$RSeOOH + O = RSeO_3H.$

The sodium salt of phenyl selenol or sodium phenyl selenolate has been oxidized electrolytically to the diselenide.

A consideration of the above properties shows a great similarity to the properties of the analagous sulphur compounds. A comparison of the properties of the selenols with those of the phenols show, however, a definite increase in the influence of the more metallic selenium atom. This is best exhibited by the oxidation of the selenols to diselenides and finally to oxygen containing acids.

Methods of Preparation. The following general methods have been used to prepare cyclic selenols:

(a) By the reaction of magnesium alkyl or aryl halides on selenium. The complexes formed yield on treatment with dilute acids, selenols and diselenides.

(b) By the reduction of the corresponding diselenide upon the addition of sodium to the diselenide dissolved in alcohol.

(c) By the hydrolysis of a selenocyanate in an alkaline solution.

(d) By the reduction of the corresopnding seleninic acid with hydrochloric acid and zinc dust.

(e) By the action of sodium selenide or sodium hydrogen selenide on a cyclic halide.

(f) By the reduction of the corresponding selenonic acid with zinc and hydrochloric acid.

(g) By the condensation of an alkali metal selenocyanate with the hydrochloride of *omega*-aminoacetophenones containing substituents in the ring.

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[3] The oxidizing agents, that have been used are, alkaline $KMnO_4$ alkaline H_2O_2, HNO_3, and bromine water (7).

[4] The oxidizing agents used to form selenonic acids include aqueous chlorine, alkaline $KMnO_4$, and 30% H_2O_2 in acetic acid.

TABLE I

THE PREPARATION OF SELENOLS

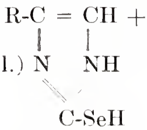
Method No.	*Equation*	*Ref. No.*
1.	$Se + RMgX + Et_2O; + H_2O + HCl = R_2Se_2 + R_2Se + RSeH +$ $Se + RMgX = RSeMgX, + HCl = RSeH + MgXCl +$ $2Se + 2RMgX = RSeH + Se(MgX)_2.$ $3Se + 3RMgX = R_2Se_2 + Se(MgX)_2.$ (X = Br, I.)	14, 20, 22. 28, 29, 30, 31
2.	$MSe + RX = RSeH + MX +$ (R = Homo- or Heterocyclic.) ($M = K_2, Na_2, NaH.$) (X = Br, Cl.)	4, 13, 23
3.	$MSeCN + RX = RSeCN; + MOH = MX + RSeH + HOCN +$ $MSeCN + RX = RSeCN + MX.$ $RSeCN + MOH = RSeH + HOCN.$ (M = Na, K.)	3, 4, 15, 20, 24
4.	$MSeCN + RN{=}NX; + MOH = RSeH + RSeCN + MX + N_2 + HOCN +$ $MSeCN + RN{=}NX = RSeCN + MX + N_2.$ $RSeCN + MOH = RSeH + HOCN.$ (R = Homo- or Heterocyclic; M = K, Na; X = Cl, Br.)	1, 2, 3, 15 16, 20.
5.	$MSeCN + RCOCH_2NH_2{\cdot}HX = R\text{-}C = CH + H_2O + MX.$ (M = K; X = Cl.) N NH C-SeH 	26
6.	$R\text{-}Se\text{-}Se\text{-}R + H_2 = 2RSeH$	1, 5, 17, 18, 19, 20
7.	$RSeOOH + 2H_2 = RSeH + 2H_2O.$ ($H = SO_2$)	27
8.	$RSeO_3H + 3H_2 = RSeH + 3H_2O.$ (H = Zn + HCl)	12
9.	Reported but not now considered to have been prepared.	8, 9, 10
10.	Methods not affecting the Se atom.	1, 2

TABLE II.

LIST OF HOMOCYCLIC SELENOLS

Selenol	*Formula*	*M. P. or B. P. °C.*	*Methods of Prep.*	*Reference Numbers*
Phenyl-	C_6H_5SeH	$B_{16}=183$	1, 6, 7, 8, 9.	8, 9, 10, 12, 14, 17, 19, 21, 27, 28, 29, 30, 31.
2-Nitrophenyl	*2*-NO_2-C_6H_4SeH	. .	4.	1, 14.
4-Nitrophenyl-	*4*-NO_2-C_6H_4SeH	. .	4.	1, 14.
2-4-Dinitro-phenyl-	*2-4*-$(NO_2)_2=C_6H_3SeH$	. .	3.	15.
2-Aminophenyl-	*2*-NH_2-C_6H_4SeH	. .	6, 10.	1, 2, 5, 11.
Picrate of 2-Aminophenyl-	*2*-NH_2-$C_6H_4SeH \cdot C_6H_2(NO_2)_3$	. .	10.	1, 2.
2-Sulfonic acid-*5*-Aminophenyl-	*2*-HO_3S-(*5*-NH_2-)-C_6H_3SeH	. .	. .	25.
4-Bromophenyl-	*4*-Br-C_6H_4SeH	M=75-7	1.	28, 29.
4-Chlorophenyl-	*4*-Cl-C_6H_4SeH	M=55	1, 3.	24, 28, 29.
4-Methylphenyl-	*4*-CH_3-C_6H_4SeH	M=46-7	1.	28, 29.
4-Ethoxyphenyl-	*4*-C_2H_5O-C_6H_4SeH	$B_{24}=156$	1.	28, 29.
2-Carboxyphenyl-	*2*-HOOC-C_6H_4SeH	. .	6.	18.
Cyclohexanyl-	$C_6H_{11}SeH$	B=170-2	1.	22.

TABLE II—Continued

Selenol	*Formula*	*B. P. or M. P. °C.*	*Methods of Prep.*	*Reference Numbers*
1-Naphthyl-	$C_{10}H_7SeH$	B=165-7	1.	20, 28, 29, 30.
2-Naphthyl-	$C_{10}H_7SeH$	M=72-4	4, 6.	4, 6, 20.
1-Anthra-quiononyl-	$C_6H_4(CO)_2C_6H_3$-SeH-*1*	M=212	2, 4.	3, 4, 16.
2-Anthra-quinonyl-	$C_6H_4(CO)_2C_6H_3$-SeH-*2*	. .	2.	4.
5-Sulfonic acid-anthraquinonyl-	*5*-HSO_3-$C_6H_3(CO)_2C_6H_3$-SCH-*1*	. .	4.	3.
8-Sulfonic acid- *2*-nitroanthraquinonyl-	*8*-HO_3S-$C_6H_3(CO)_2C_6H_2(NO_2$-*2*$)$SeH-*1*	. .	2.	4.

TABLE III.

LIST OF HETEROCYCLIC SELENOLS

Selenol	*Formula*	*M. P. °C.*	*Methods of Prep.*	*Reference Numbers*
5-Acridinyl-	$C_6H_4=C(SeH)\text{-}N=C_6H_4$	238	2.	13.
1-Ph-3-Me-4-Bz-pyrro-(a)monazolyl-5- (2 modifications)	$Ph\text{-}\underline{N\text{-}N=C(Me)C}Bz\text{-}CSeH$	96 and 116	2.	23.
3-(3′-4′-Dimethoxy Ph)-pyrro(b)monazolyl-5-	$(MeO)_2=C_6H_3\text{-}\underline{C=CH\text{-}NH\text{-}C(SeH)=N}$	115-7	5.	26.
3-(4′-5′-Dimethoxy-2′-tolyl)-pyrro(b)monazolyl-5-	$(MeO)_2=C_6H_2(Me)\text{-}\underline{C=CH\text{-}NH\text{-}C(SeH)=N}$	159-63	5.	26.

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THE ANTIGENIC PROTEINS OF SALMONELLA AERTRYCKE

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It has been established by the work of various investigators—Wells (16, 17), Osborne (15), and others—that purified proteins with few exceptions can be successfully used as antigens. Commonly in the immunization of an animal to a bacterial antigen, however, the whole cell or cell autolysate is used. In the bacterial cell there may be present several different proteins which are antigenic, although little is known in this connection.

The object of this study was to separate various fractions of bacterial protein and determine the antigenic properties of each. The test organism used was *Salmonella aertrycke* which, when used in the form of whole cells, results in the production of a high titred immune serum.

METHOD AND TECHNIQUE

Preparation of the Antigens. The bacteria were grown on two per cent nutrient agar (pH 7.2) in Blake bottles. The agar was allowed to harden with the bottles lying flat. The surface of the agar was flooded with a heavy twenty-four hour broth culture of *Salmonella aertrycke* and was incubated for twenty-four hours at thirty-seven degrees C. The bacteria were then washed down with sterile distilled water, and the suspension was centrifuged in order to concentrate the bacteria, which were placed in a dessicator over phosporous pentoxide and dried. The weight of the dried bacteria obtained by this procedure was 1.3534 grams.

Methods used in the preparation and isolation of the various fractions were taken chiefly from Mathews' Physiological Chemistry (14) and from a review in Lovett's paper (13) on the quantitative relations of serum albumin.

The fractions which were prepared from the dried bacteria were separated on the basis of solubility. The water soluble substances were separated from the saline soluble, from the alkaline soluble, and from the ether soluble. This was done in the following manner:

A portion of the dried bacteria was suspended in saline and used as Fraction I.

The remaining part of the dried bacteria was ground up in 70 c.c. of distilled water, and the residue was separated by centrifuging. The supernatant fluid, solution A (Chart I) presumably contained both albumin and pseudoglobulin. Some of it was used as Fraction II.

In order to separate the albumin from the pseudoglobulin, the rest of the supernatant fluid was added to an equal volume of ammonium sulphate (100%), which precipitated the pseudoglobulin. This was sepa-

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rated by filtration and the filtrate, containing albumin, was dialized free of ammonium sulphate and was diluted up to 70 c.c. Sodium chloride was added to make the salt concentration equal to that of physiological saline. This solution was used as Fraction III.

The pseudoglobulin precipitate was suspended in 70 c.c. of normal saline, dialized free of ammonium sulphate, and used as Fraction IV, sodium chloride being added to replace that lost in dializing.

The residue which would not dissolve in distilled water was ground with 10 c.c. physiological saline, after which the mixture was centrifuged. The saline supernatant fluid, Solution B, presumably contained globulin and probably also other proteins. This was diluted up to 70 c.c. and some of it was used as Fraction V.

In order to precipitate the globulin, the rest of the solution was added to an equal volume of ammonium sulphate (100%). The precipitate was separated by filtration, and the filtrate was discarded. The precipitate was suspended in 70 c.c. physiological saline and dialized free of ammonium sulphate. Sodium chloride was added to replace that lost in dializing, and this suspension was used as Fraction VI.

The residue which did not dissolve in the saline solution (Solution B) was ground in 100 c.c. sodium hydroxide and the mixture was centrifuged. The fluid, which presumably contained conjugated proteins, was diluted up to 70 c.c. and used as Fraction VII. The residue was extracted with ether, which was removed and evaporated. The dry residue from this evaporation was suspended in 70 c.c. physiological saline and was used as Fraction VIII.

Protein and Lipoid Tests. Differential tests were used to determine the protein constituents of the soluble fractions, and a lipoid test was made on Fraction VIII. The results of these are shown in Table II.

The Biuret test is not a test for any specific amino acid but is dependent on the peptid linkage. A positive reaction is given by all native proteins and by the larger number of the derived products. It is not so delicate as some of the other tests. Fractions I, II and V gave positive results.

The xantho-proteic reaction is given by tryptophane, tyrosine, and phenyl alanine, the three amino acids having benzene nuclei. Positive reactions were given by Fractions II and VII.

The Adamkiewicz reaction depends on the presence of tryptophane. The results were negative throughout; so probably the positive reaction given by Fraction VII in the xantho-proteic test was due to tyrosine or phenyl alanine, since the Millon test, for tyrosine (benzene nucleus) was also positive, and the tryptophane test was negative. Number VII was the only fraction which gave a positive reaction with the Millon test.

Ehrlich's diazo reaction is a histidine and tyrosine test. A positive reaction for histodine was given by Fraction IV, while all the others except VI were positive for tyrosine.

A test was made for the presence of Cysteine or Cystine by boiling the solutions with sodium hydroxide and adding lead-acetate solution. The results were entirely negative.

Tests were also made for heat coagulation, but there was no perceptible change in any solution.

The ether extract was tested with osmic acid and was negative. It was also negative with all the protein tests, except Ehrlich's diazo reaction, in which it was slightly positive. As shown in tables III and IV, it apparently had no antigenic properties.

Inoculation. Twenty-four rabbits were inoculated intravenously, three rabbits to each fraction. Each rabbit received a total of seven inoculations, which were given at three day intervals. The amount of each was as follows:

Inoculation I	0.1 c.c.
Inoculation II	0.1 c.c.
Inoculation III	0.1 c.c.
Inoculation IV	0.2 c.c.
Inoculation V	0.3 c.c.
Inoculation VI	0.4 c.c.
Inoculation VII	0.5 c.c.

Since each fraction was diluted up to or suspended in 70 c.c. of fluid, an inoculation of 0.1 c.c. is equal to 1/700 of the total amount of that fraction. The rabbits were bled before the inoculations were started, and the sera were tested for agglutinins and precipitins, with entirely negative results. The dilutions used in determining titres were set up in this way: A series of ten tubes was used for each serum, the tenth tube being a saline control. In the first tube was placed one and eight-tenths c.c. of physiological saline. Each succeeding tube received one c.c. Two-tenths c.c. of serum was placed in tube I and thoroughly mixed. This gave a dilution of one to ten. One c.c. of this was removed and added to the saline in tube II, giving a dilution of one to twenty. This was thoroughly mixed, and one c.c. was removed and added to the saline in tube III, giving a dilution of one to forty, etc.

EXPERIMENTAL DATA

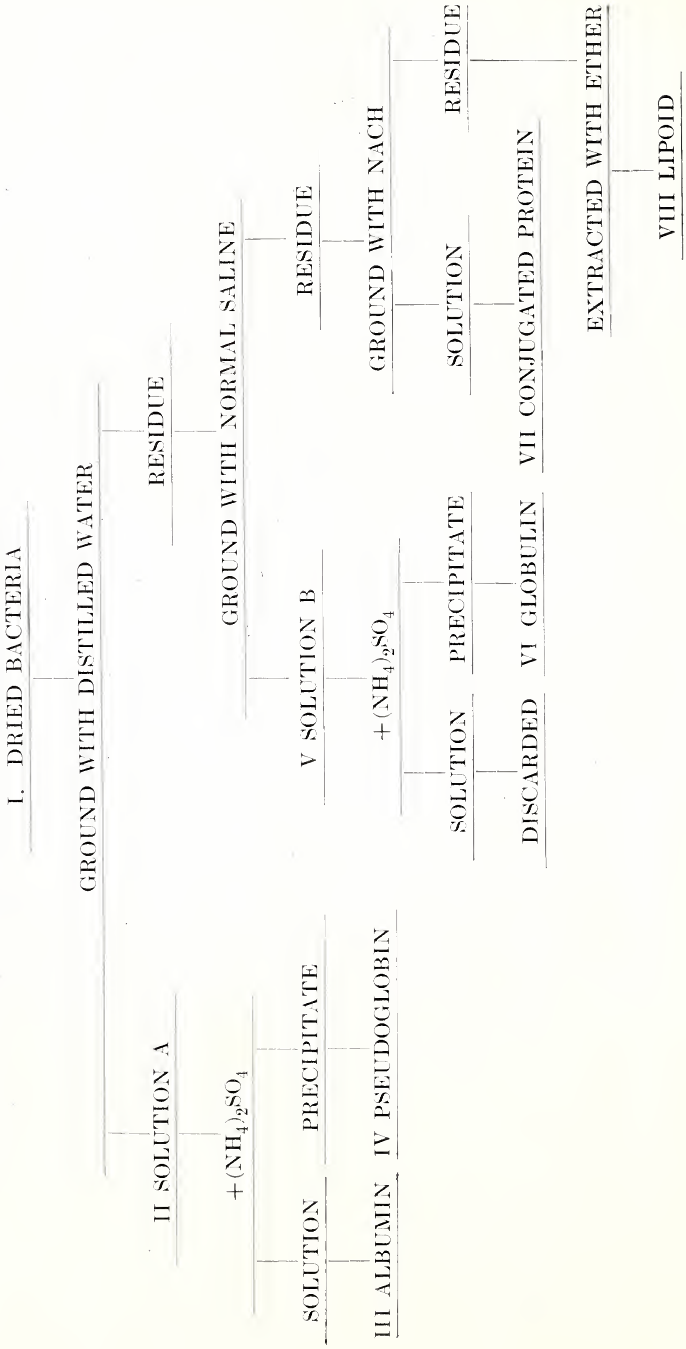
One week and two weeks respectively after the last inoculation the rabbits were bled and the sera tested for agglutinins and precipitins. Each fraction was then tested with each serum for cross agglutinations and precipitations. The results, shown in Tables III and IV, are:

Fraction I: dried bacteria
precipitins.......negative
agglutinins 1:2560
cross agglutination and precipitation...negative.

Fraction II: albumin and pseudoglobulin mixture
precipitins.......1:40
agglutinins ......negative
cross agglutination and precipitation...negative.

Fraction III: albumin
precipitins.......1:80
agglutinins ......negative
cross agglutination and precipitation...negative.

TABLE I—PROTOCOL OF THE FRACTIONATIONS—(NUMBERS INDICATE FRACTIONS)



Fraction IV: pseudo-globulin
precipitins.......negative
agglutinins ......negative
cross precipitations and agglutinations...with sera of rabbits eight and nine, immunized to Fraction V...precipitation in a dilution of one to ten.

Fraction V: globulin and undetermined proteins
precipitins.......1:80
agglutinins ......negative
cross agglutination and precipitation...0

Fraction VI: globulin
precipitins.......negative
agglutinins ......negative
cross agglutination and precipitation...with sera of rabbits eight and nine, immunized to Fraction V...precipitation in a dilution of one to ten.

Fraction VII: conjugated protein
precipitins.......1:10
agglutinins ......negative
cross agglutination and precipitation...negative.

Fraction VIII:
precipitins.......negative
agglutinins ......negative
cross precipitation and agglutination...negative.

DISCUSSION AND SUMMARY

In this work attention was focused on the production of antibodies and not on the production of a high titred serum.

The titres produced by antigens other than whole bacteria, although low, were definite.

Cross precipitations, which occurred in only two cases, were in dilutions too low for the use of absorption.

Fraction I, whole bacterial protein, gave positive protein tests with Ehrlich's diazo reaction and the Biuret test, but was negative with all other protein tests applied. This fraction was strongly antigenic. Fraction II, corresponding to a mixture of albumin and pseudoglobulin, gave positive tests with the diazo reaction, the Biuret test, and the xanthoproteic test. This fraction was also antigenic. Fraction III, corresponding to purified albumin, was positive only with the diazo reaction, but was antigenic. Fraction IV, corresponding to pseudoglobulin, was positive for histidine only and was not antigenic. This test was not obtained on any other fraction. Fraction V, corresponding to a mixture of globulin and unknown proteins, was positive with the diazo and Biuret tests and was antigenic, while Fraction VI, separated from V and corresponding to globulin, was negative with all protein tests and was nonantigenic. Fraction V thus contained some other undetermined antigenic protein or proteins. Fraction VI, consisting presumably of conjugated proteins, gave a positive diazo reaction, positive xantho-proteic and positive Millon. This fraction was antigenic and was the only one which gave a plus Millon reaction. Fraction VIII, presumably lipoid, was negative for lipoids by the osmic acid test, but apparently contained traces of protein, probably as impurities, since a faintly positive diazo reaction was obtained. It was not, however, antigenic.

From a consideration of the above it will be seen that only those fractions which gave tests for the benzene nucleus were antigenic. This is in accord with the accepted idea that the presence of aromatic amino acids is necessary for antigenic activity on the part of a protein.

The protein of *Salmonella aertrycke,* under the conditions here reported, does not appear to contain either globulin, pseudoglobulin, or lipoid.

CONCLUSIONS

1. It has been found possible to separate specific antigenic fractions from the whole bacterial protein of *Salmonella aertrycke.*
2. The whole bacterial protein, under the experimental conditions of this work, was a more powerful antigen than any of the fractions tested.
3. The antigenic fractions obtained corresponded to a mixture of albumin and pseudoglobulin, albumin, a mixture of globulin and undetermined proteins, and conjugated proteins. Since tests for globulin and pseudoglobulin were negative, this indicates that there are present as antigens, albumin, conjugated protein, and some other protein or proteins as yet undetermined.

TABLE II—PROTEIN AND LIPOID TESTS ON VARIOUS FRACTIONS

Fraction	Biuret	Xantho-Proteic	Adam-kiewicz	Millon	Ehrlich's Diazo	Lead Acetate	Heat	Osmic Acid
I	+	0	0	0	+ Tyrosine	0	0	
II	+	+	0	0	+ Tyrosine	0	0	
III	0	0	0	0	+ Tyrosine	0	0	
IV	0	0	0	0	+ Histadine	0	0	
V	+	0	0	0	+ Tyrosine	0	0	
VI	0	0	0	0	0	0	0	
VII	0	+	0	+	+	0	0	
VIII	0	0	0	0	+ (Faint) Tyrosine	0		0

TABLE III—PRECIPITATION AND AGGLUTINATION TITRES

Frac.	One week after last Inoculation			Two weeks after last Inoculation	
	Rabbits	Agglutinins	Precipitins	Agglutinins	Precipitins
I	22	1:1280		1:1280	
	22	1:2560		1:2560	
		1:320		1:320	
II	1	0	1:40	0	1:40
	2	0	1:10	0	1:20
	3	0	1:40	0	1:20
III	10	0	1:40	0	1:80
	11	Dead			
	12	0	1:20	0	1:40
IV	4	0	0	0	0
	5	0	0	0	0
	6	0	0	0	0
V	7	0	1:40	Dead	
	8	0	1:40	0	1:80
	9	0	1:20	0	1:80
VI	13	0	0	0	0
	14	0	0	0	0
	15	0	0	0	0
VII	16	0	0	0	1:10
	17	0	0	0	0
	18	0	0	0	1:10
VIII	20	0	0	0	0
	21	0	0	0	0
	24	0	0	0	0

TABLE IV—CROSS AGGLUTINATIONS AND PRECIPITATIONS

H.S. = homologous serum

Fractions	I	II	III	IV	V	VI	VII	VIII
Rabbits 1	0	H. S.	0	0	0	0	0	0
2	0	H. S.	0	0	0	0	0	0
3	0	H. S.	0	0	0	0	0	0
4	0	0	0	H. S.	0	0	0	0
5	0	0	0	H. S.	0	0	0	0
6	0	0	0	H. S.	0	0	0	0
7	0	0	0	0	H. S.	0	0	0
8	0	0	0	1:10	H. S.	1:10	0	0
9	0	0	0	1:10	H. S.	1:10	0	0
10	0	0	H. S.	0	0	0	0	0
11	Dead	0	H. S.	0	0	0	0	0
12	0	0	H. S.	0	0	0	0	0
13	0	0	0	0	0	H. S.	0	0
14	0	0	0	0	0	H. S.	0	0
15	0	0	0	0	0	H. S.	0	0
16	0	0	0	0	0	0	H. S.	0
17	0	0	0	0	0	0	H. S.	0
18	0	0	0	0	0	0	H. S.	0
19	H. S.	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	H. S.
21	0	0	0	0	0	0	0	H. S.
22	H. S.	0	0	0	0	0	0	0
23	H. S.	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	H. S.

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THE EFFECTS OF THE CIRCULATION OF INSULATING OILS UPON THEIR DIELECTRIC PROPERTIES

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Insulating oils are often used for the additional purpose of aiding in the dissipation of the heat generated in adjacent portions of the circuits. If, in such cases, the oil is forced to circulate or is left free to circulate by convection, the variations in motion, pressure, and temperature will affect the capacitance of the circuits. In those circuits in which the capacitance must be controlled with some degree of precision, as is especially necessary in high frequency circuits, the effects of the above named variations upon the dielectric properties of the oil may prove to be disturbing factors of some importance. Hence, when it became convenient in connection with some other work, the magnitudes of these effects were determined for a high grade, heavy, paraffin oil (specific gravity, .875; dielectric constant, 2.066).

Two test condensers were mounted in a steel cylinder which was connected to an oil reservoir of constant pressure head in such a way that the flow of oil through the condensers might be reversed. These condensers were constructed of heavy, circular, metal plates perforated by small holes which were symmetrically arranged and spaced so as not to decrease the rigidity of the plates. The condensers differed in insulation, metal, and construction so that a check of the effects produced in them eliminated all condenser characteristics. The oil flowed in a direction perpendicular to the plates and parallel to the electric field. The total capacities of the condensers were 147.3 mmf and 139.1 mmf, of which the amounts affected by the oil dielectric were 30.55 mmf and 36.41 mmf, respectively. A heterodyne method of measuring the changes in capacity was used in which a change of frequency of one cycle per second was easily observable. A frequency of 640 kc was used on the fixed frequency oscillator. The usual precautions were taken regarding shielding, temperature, vibrational disturbances, and sources of A and B potentials. Pressure gauges placed in the housing at the ends of the condensers gave the pressure drop through them and the mean pressure of the oil in each condenser. After the effects due to the flow were noted the condensers were placed under the same mean pressures with the oil stationary. The effects due to the pressure changes which produced the flow were thus obtained and deducted from the total effect. Fig. 2 shows the relation between pressure and capacity through a considerable range.

Fig. 1 shows the total effect of the flow of the oil upon the capacity and also the effect of the pressure reductions upon which the flow was consequent. A rate of flow of 10 cm. per sec. was sufficient to decrease the generalized dielectric constant by about .06 per cent. One-third of

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this change was due to the accompanying decrease in pressure. The remaining decrease in capacity indicates that the cause may be found in changes of the conductivity of the oil. In order to verify this the condensers were placed in an oscillating circuit in which the regenerative coupling had been adjusted until the current was independent of the frequency. The flow of oil was found to reduce the current. Since the current had been made independent of the capacity, this reduction in current was due to a decrease in the parallel resistance of the condenser, or, in other terms, to the increased conductivity of the oil. Numerous explanations of this increased conductivity suggest themselves, such as orientation phenomena, actual changes in the number of ions present, or the addition to the a. c. carried by the condenser of a d. c. component carried by the mass movement of the liquid.

The probability of any appreciable polarization in a straight-chain hydrocarbon of this type is very small,[1] but orientation losses due to other causes[2] might be expected to increase with the rate of flow in condensers of this type. An increase in ionization seems very unlikely, the only condition possibly conducive to this being the very slight temperature variation during the flow. The effect of temperature upon the dielectric constant of paraffin oil has been investigated by Butman,[3] who found the relation to be linear with a change of slope at 50° C. There are two temperature variations which oppose one another during the flow. The very small temperature rise caused by the mechanical agitation during the flow tends to increase the capacity slightly. On the other hand, the flow is always accompanied by a decrease of pressure, and the temperature was found to vary directly with the pressure, as in Fig. 3. This was investigated by immersing a calibrated thermocouple in the paraffin oil in a high-pressure piezometer. As these temperature changes were small and tended to compensate, their effect upon ionization must have been negligible. It seems probable, therefore, that the chief factor in the production of increased conductivity was the mass

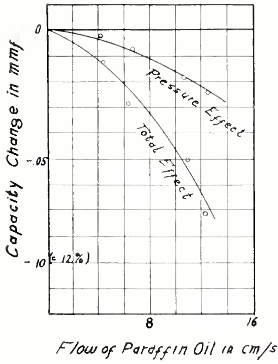

Fig 1

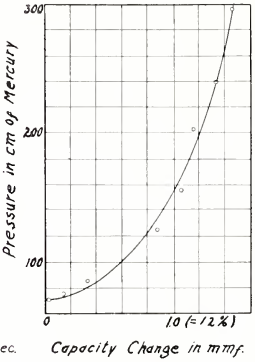

Fig. 2

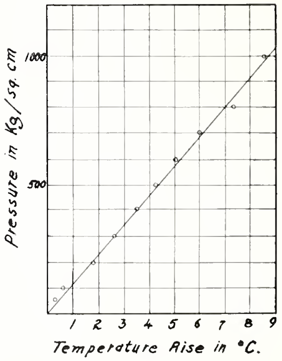

Fig. 3

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[1] F. Hamburger, Jr., Phy. Rev., 35:1119, 1930

[2] P. Debye, "Polar Molecules", p. 109.

[3] G. A. Butman, El. World, 71:812. 1918.

movement of the liquid along the electric field, such a flow being equivalent to an increase in the mobility of the ions present. In a condenser consisting of co-axial, cylindrical plates the maximum obtainable flow of 2.4 cm per second produced no effect upon the capacity except that produced by the decrease in pressure during the flow. As this flow was perpendicular to the electric field, the mass movement of the ions did not increase the conductivity.

Benzene was taken through the same procedure as was the paraffin oil and it exhibited similar characteristics. Its dielectric constant, however, was much more sensitive to pressure changes, a change of pressure of 45 cm of mercury producing a variation of .1 per cent in the dielectric constant.

In general, any motion given a liquid, whether by vibration, convection currents or forced circulation, considerably affects the generalized dielectric constant of the liquid, the chief effect being an increase in conductivity caused by the ionic current accompanying the flow.

This investigation was carried out at Indiana University under the very helpful direction of Professor R. R. Ramsey.

COMPARATIVE STUDIES ON MERTHIOLATE WITH REFERENCE TO LABORATORY EVALUATION AND HUMAN TISSUE ANTISEPSIS

H. M. POWELL and W. A. JAMIESON, Lilly Research Laboratories, Indianapolis

The study of materials intended for use as germicides includes a voluminous list of publications and reports dealing with many substances and various methods of technique. It is not the aim in this paper to analyze these reports in detail, or to deal in a comprehensive way with this mass of data. In a brief way, however, attention should be drawn to the main ideas embodied in this literature, the general nature of experimentation, and the conclusions arrived at, followed by the examination of our experimental material.

I. **The Natural Antibacterial Mechanism.** One may safely state that of all antibacterial mechanisms thus far studied, the natural resistance of the body cells is the most effective. Countless times during the life of the individual, invading bacteria and foreign materials are successfully dealt with by the normal or immune antibacterial mechanism of the individual. The success of this mechanism is attested by the survival of the species, and the balance between disease organisms on the one hand and the host on the other. One may well note the change in the notion of infection in the last generation, involving a shift of attention from the original simple study of the virulence of the bacteria to considerations of the various lines of defense presented by the host. In other words, the mere bringing together of virulent bacteria and an apparently susceptible host does not regularly result in infection. The conditions under which so-called carriers develop include a nice balance of offensive and defensive agencies. In all of this natural resistance to infection as just set forth, one may attribute survival of the host to antibacterial reactions, including the normal integrity of epithelial and other barriers, the influence of antibodies on the infectious agent followed by an accelerated phagocytic action and digestion, and the influence of fever temperature on this whole mechanism.

II. **Fortification of Body Immunity.** The practical utilization of germicides has appeared most desirable as a method of fortifying natural resistance. Considerable interest is attached to the possibly successful artificial medication of an infecting bacterium, and this no doubt has been the incentive in the development of many drugs and chemicals to serve as germicides, as has been the case in parallel studies on various specific antisera.

III. **General Evaluation of Germicides.** The main method of examination of substances intended as germicides in the past has been an

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in vitro or test tube test in which certain bacteria are exposed to a solution of chemical for a time, following which cultivation of any remaining viable organisms is attempted. The medium in which this medication has been brought about has usually been a very watery mixture and one cannot surely interpret the results in terms of effectiveness in tissue antisepsis. The actual manner of killing of exposed bacteria may be coagulation of the bacterial substance, rupture of vital parts, or poisoning of respiratory or reproductive mechanisms. There has been little information as to the exact time of death of medicated bacteria, and negative results in cultivation attempts mean only that such bacteria will no longer proliferate in the usual way. Whether all

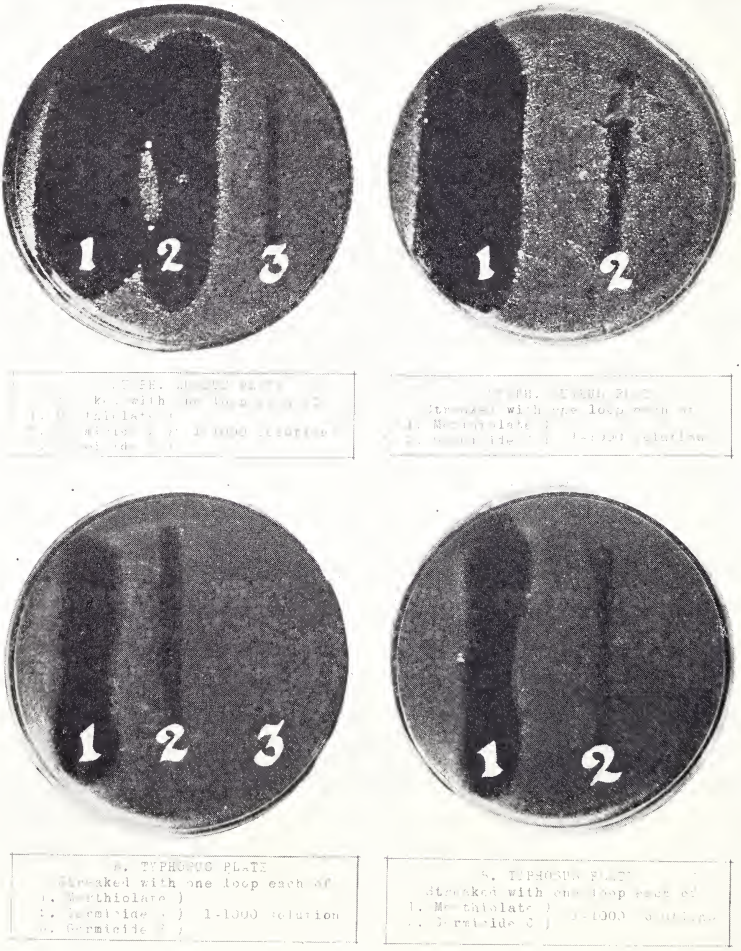

Fig. 1

of the vital functions of such treated bacteria, in addition to reproduction, have ceased at the end of the medication period is not, of course, determined by the usual culture experiments.

IV. **Modifications of Germicide Evaluation.** In general one finds that too few species of bacteria have been examined in germicide

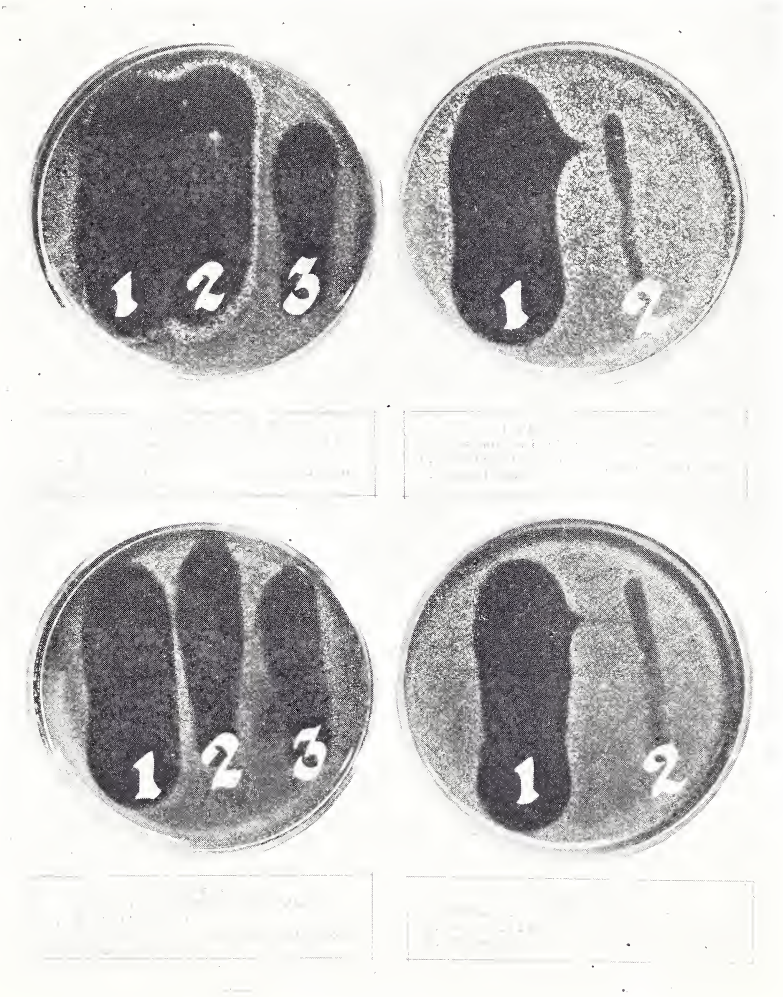

Fig. 2

studies. It would be much safer to base conclusions on wider studies including many different bacteria. In many studies, even though many bacteria have been used, there is an almost total disregard of the question as to whether the mechanism of bacterial killing brought about in a very watery medium in a test tube would be at all applicable to actual tissue antisepsis in which the medium of medication is a semisolid of high protein content. A third important criticism of a large amount of previous work is that due attention has not been paid to the compatibility of germicide and body tissues and whether the use of such germicide may not outrage already insulted and inflamed tissues. Certainly one cardinal property of a germicide should be its freedom from tissue-injuring properties. The germicide of choice should at least do no harm. One may now go farther and inquire whether the germicide in question positively has a beneficial effect upon the tissues. This is departing at some length from the older ideas that germicides are proved or disproved in test tube experiments including phenol co-

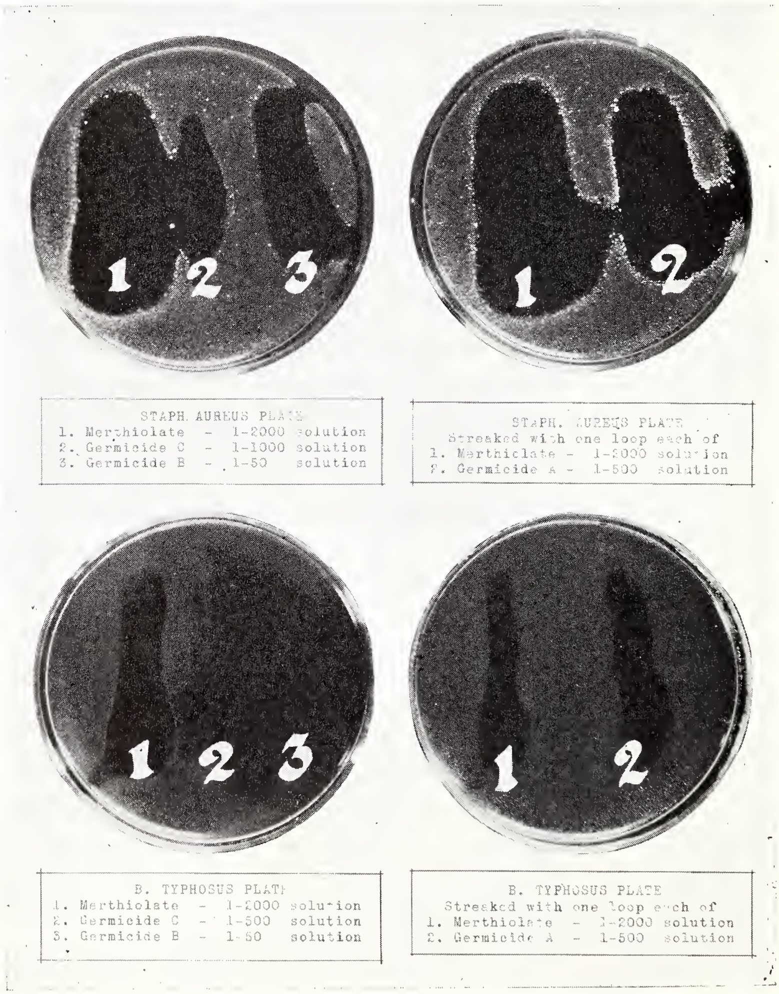
1
2
3
1
2
STAPH. AUREUS PLATE
1. Merthiolate - 1-2000 solution
2. Germicide C - 1-1000 solution
3. Germicide B - 1-50 solution
STAPH. AUREUS PLATE
Streaked with one loop each of
1. Merthiolate - 1-2000 solution
2. Germicide A - 1-500 solution
1
2
3
1
2
B. TYPHOSUS PLATE
1. Merthiolate - 1-2000 solution
2. Germicide C - 1-500 solution
3. Germicide B - 1-50 solution
B. TYPHOSUS PLATE
Streaked with one loop each of
1. Merthiolate - 1-2000 solution
2. Germicide A - 1-500 solution

Fig. 3

efficient determinations. The germicide of choice may now be expected to contain components which promote tissue repair and healing.

V. **Properties of the Ideal Germicide.** The ideal germicide should have ample germicidal value as proven in media most nearly like the tissues. In tissue antisepsis this property may be expected to reduce

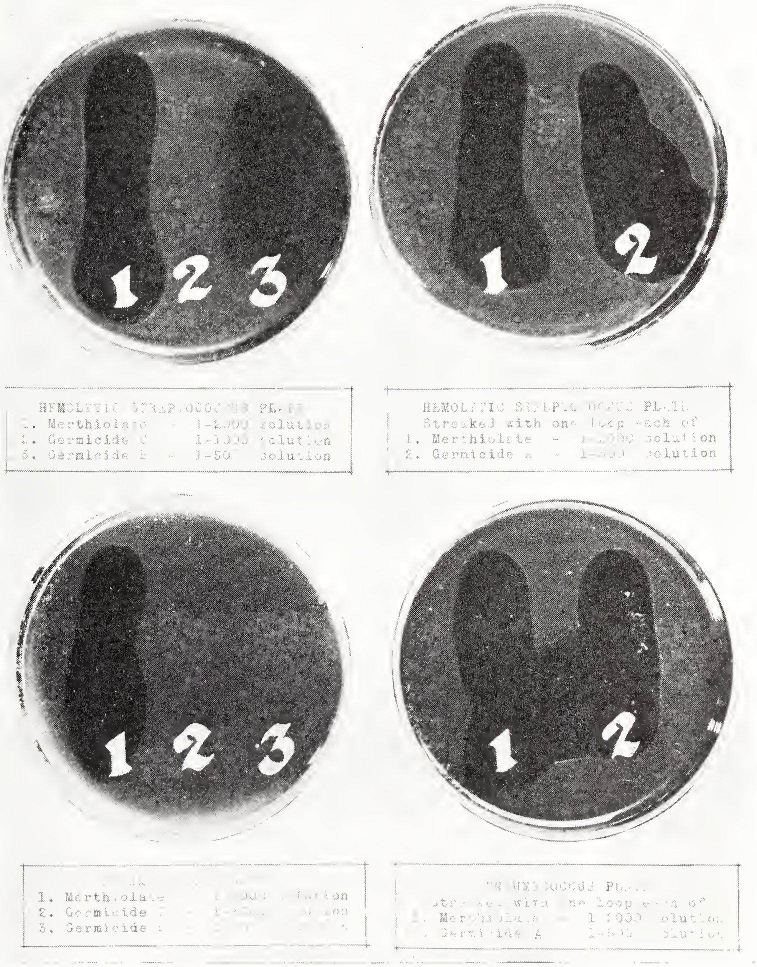
1
2
3
1
2
HEMOLYTIC STREPTOCOCCUS PLATE
Merthiolate - 1-2000 solution
Germicide C 1-1000 solution
Germicide B - 1-50 solution
HEMOLYTIC STREPTOCOCCUS PLATE
Streaked with one loop each of
1. Merthiolate - 1-1000 solution
2. Germicide A - 1-500 solution
1
2
3
1
2
1. Merthiolate
2. Germicide
3. Germicide
PNEUMOCOCCUS PLATE
Streaked with one loop each of
Merthiolate - 1-1000 solution
Germicide A 1-500 solution

Fig. 4

the number of viable infecting organisms. The ideal germicide should have bacterial inhibitory properties in high dilution, so that the diminished infectious process shall be held in check for several hours instead of reappearing as formidably as ever in a short time after treatment. The ideal germicide should not cause precipitation of proteins, and should dialyze freely and thus penetrate sufficiently easily, as proven in the laboratory, to indicate usefulness in actual tissue antisepsis. Along with these properties, and that of low toxicity, should be coupled the property of promoting healing.

The considerations just set forth have been recorded in some detail since it appears that tissue antisepsis is a much more complex subject than has usually been appreciated. The subject is an involved one in which ordinary phenol coefficients mean very little, and the ease of accomplishing tissue sterility has been greatly overestimated. Proper importance may now be placed upon the nature of the medium in which medication is attempted, and the optimum relations between the germicide and the tissues.

In the light of this broader conception of the nature of tissue antisepsis and the natural difficulties involved it is proposed to examine the new chemical, *Merthiolate,* as a germicidal agent of a new type.

EXPERIMENTAL

I. **General Properties of Merthiolate.** Merthiolate may be chemically identified as the sodium salt of ethyl mercuri thiosalicylic acid. Evidence has previously been presented (1) showing that Merthiolate has many desirable properties indicating its probable usefulness as a germicide. Chief among these may be mentioned its great solubility in body fluids as well as water, its very low toxicity in large doses for experimental animals and man, and its uniform germicidal effectiveness and bacteriostatic action against many human pathogens. These studies covered a wide range of tests, and placed greatest emphasis on experiments designed to approximate as nearly as possible the physical and chemical conditions obtaining in the tissues. Tissue antisepsis was not confounded with killing bacteria suspended in water. Precautions were used in all tests to evaluate properties possible of utilization and realization in tissue antisepsis. In these studies it was found that the action of some chemicals which are effective germicides in water is almost entirely blocked in serum and fibrin media most closely resembling the tissues. Unwarranted assumptions, either stated or assumed, as to effectiveness in tissue antisepsis should not be made on the basis of test tube results alone.

II. **Comparative Action of Merthiolate in Semisolid High Protein Media.** Certain modified experiments on comparative germicidal action may be described which serve to give a better estimation of germicidal excellence than the usual test tube experiments. Different dilutions of Merthiolate and other germicides have been applied as streaks across poured agar plates of various pathogens. Veal infusion agar has been used alone or with various contents of serum, or fresh plasma plus calcium chloride to cause clotting as the agar solidifies. In this way one has a medium of agar, serum agar, or fibrin agar, including the desired bacteria throughout the mass. Routinely 15 cc. of medium were mixed with 0.1 cc. of a twenty-four hour culture in each plate. Plates prepared in this way were streaked with a three millimeter loop of dilutions of Merthiolate and other well known commercial germicides, after which they were incubated for twenty-four hours at 37° C. At this time clear zones about the streaks indicated the degree of penetration and antibacterial action. In order to judge whether the substance in question had killed or only inhibited the organisms included in the cleared agar area for a short time, small blocks of the latter were regularly removed and cultured to tubes of fresh broth. In these tests, utilizing a 20 per cent serum agar medium, as shown by plates I to IV,[1] Merthiolate and Germicide A alone were regularly germicidal. It may be mentioned that Germicide A is ten times as toxic as Merthiolate. Germicides B and C were not effective in these tests although they bring about germicidal effects in water. Preliminary watery dilution test tube tests of Merthiolate had shown that this chemical has forty to fifty times the germicidal action of phenol. These results were confirmed by Marshall (2).

III. **Comparative Action of Merthiolate on Living Tissues in Vitro.** It is not assumed that the serum agar plate tests just described are the best that can be designed for obtaining accurate information on the properties of a germicide indicating excellence in tissue antisepsis. Recently Buchsbaum and Bloom (3) have carried out experiments with several well known germicides in which both bacteria and living tissues growing *in vitro* were utilized. The tissues are propagated by well known methods devised by Carrel and others. In this study Buchsbaum and Bloom prepared tissue cultures together with bacteria and various concentrations of germicides, and attempted to find the limits in regard to tissue injury and bacterial killing. Using the score of 1 for an ideal antiseptic, i.e., one which at the weakest concentration would kill the bacteria and yet in this concentration not damage the tissues in the slightest, it was found that Merthiolate would receive a score of 0.9, which was the highest in the list and the closest approach to the ideal.

IV. **Action of Merthiolate on Labile Antigens and Antibodies.** It has been shown (4) that Merthiolate is practically non-injurious to various labile antigens and antibodies. Hemotoxins as well as the more stable toxins are little affected by Merthiolate, and presumably, due to the low ionization rate of this chemical and resulting lack of injury to serum globulins, antibodies are very little if any affected by Merthiolate. For these reasons this chemical is being used quite widely as a preservative for bacterial vaccines and antisera for human use. It may be supposed that Merthiolate would have a less severe action on immunity processes than other germicides having greater tendencies toward destruction of the agents of such processes, namely, antigens and antibodies. Lack of interference with the normal defensive action of the body would constitute a very worth while property of a germicide.

V. **Direct Action of Merthiolate on the Tissues.** Reiman (5) and others have shown the importance of sulphydryl in the multiplication of cells in repair and healing. So pronounced is this effect of sulphydryl in stimulating tissue growth that it amounts to practically a general law. Since Merthiolate contains a substituted sulphydryl group it became of interest to examine the healing properties of this germicide. Results of this study have been completed (6). This work may be summarized as follows:

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[1] Fairly clear photographs were obtained for all plates except one, namely the B typhosus plate in the lower left corner for Figure 3. Here germicide B is obscured by a shadow, while only a little of the germicide C streak is seen.

In tests in which the indirect effect of germicide on tissues was ruled out (i.e., antibacterial action may be confused with tissue stimulating properties) it was found that Merthiolate promoted rapid production of new epithelium and granulation tissue in the same way that other thio compounds acted. Denuded areas were covered with epithelium which rapidly closed in as a ring like the diaphragm on a camera. A non-sulphydryl containing mercurial germicide used as a control did not specifically stimulate healing, while thiocresol used as a second control stimulated rapid healing. It appears that no studies of this type have been reported in connection with any other germicides in common use. Development of germicides with healing properties, as well as antibacterial properties, represents a new and important development in antisepsis.

We are indebted to Dr. G. H. A. Clowes and Mr. H. A. Shonle of the Lilly Research Laboratories, and to Dr. M. S. Kharasch of the University of Chicago, for suggestions and advice during the course of this study.

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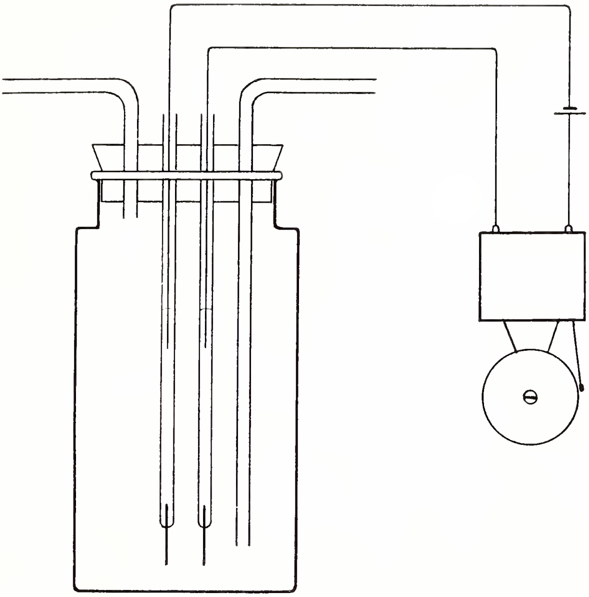
A TRAP BOTTLE WITH AUTOMATIC ALARM

Thomas H. Vaughn, Notre Dame University

Experiments with liquid ammonia at its boiling point are ordinarily performed under a good hood. In many cases, however, the small table space available in the usual hood offers serious difficulties in the setting up of large pieces of apparatus. In such cases it is common practice to set up the apparatus on the ordinary laboratory desk and to pass any evolved gaseous ammonia into running water. This arrangement is satisfactory in most instances. At times, however, water is sucked back into the ammonia. An ordinary trap bottle is of little value here, for when placed in the gas line it merely catches water until full, and then ceases to operate. For this reason the bottle must be constantly watched in order to detect any flow of water into the system.



After the loss of several experiments in which liquid ammonia was used as a solvent, the trap bottle was modified in such a manner as to give an audible alarm in the event that water was drawn into the apparatus.

The design of the device is apparent from the cut. It consists of an ordinary trap bottle modified by the insertion through the stopper of two glass tubes into the bottom of which platinum wires are sealed.

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The tubes are partly filled with mercury, and connection to a source of current and a door bell is made as shown.

The operation of the bottle is very simple. After placing 10-15 grams of sodium chloride or other ionizable salt in the bottle, it is placed in the exit line in the usual manner. Should water be drawn into the apparatus the salt dissolves and the resulting solution closes the bell circuit, sounding an alarm.

By choosing a large bottle and by making the lumen of the exit tube small, a large time interval between the sounding of the bell and the filling of the bottle can be obtained. This allows sufficient time for the disconnection of the apparatus.

This apparatus has been successfully used in the absorption of both hydrogen chloride and ammonia.

THE DOUBLE DECOMPOSITION REACTION

ERNEST A. WILDMAN, Earlham College

The many new methods of investigating sub-atomic phenomena that have been developed chiefly by physicists during the last twenty-five or thirty years have given us a knowledge of the nature of chemical reactions and chemical compounds that entirely overshadows the theoretical knowledge of the chemists at the beginning of the present century. Merely a partial list for the last twenty years alone includes such significant discoveries and theories as Rutherford's nuclear atom, Laue's X-ray crystal analysis and the modifications and improvements by the Braggs and others, Moseley's determination of the relative atomic numbers and Chadwick's absolute determination, the Bohr theory, the Lewis-Langmuir theory, polar and non-polar compounds, electrovalence and covalence, the Debye-Huckel theory of complete ionization and interionic attraction of strong electrolytes, Millikan's exact determination of $\frac{e}{m}$, Rutherford's artificial disintegration of light atoms, Aston's mass spectrograph and the isotopes, the packing effect and evidence of the change of mass into energy, the cosmic rays and Millikan's theory of the synthesis of matter from radiation, the theory of wave mechanics, and the Heisenberg atom.

These subjects may all be said to fall within the scope of atomic and sub-atomic physics, and yet they have changed the appearance of a large part of theoretical chemistry to such an extent as to make it an almost unrecognizable science to a chemist of 1900.

In contrast to the situation that existed at that date we now know how many elements there are between hydrogen and uranium; why most atomic weights deviate largely from whole numbers while some do not; that atoms, molecules, and ions are now established facts, for we can measure their individual sizes and weights, their relative positions with respect to each other in substances and the number of them in a gram. We can even measure changes in the size of atoms due to the loss of valence electrons when they are oxidized to positive ions or the gain of such when they are reduced to negative ions.

These and many other recent advances certainly suggest the fitness of re-examining the stock ideas of the presentation of general chemistry. It is the purpose of this paper to do so for the double decomposition reaction.

Most of the reactions that a student in inorganic chemistry and qualitative analysis deals with have been included by conventional classification in this type. The most common examples have been reactions in which a precipitate is formed, such as the formation of in-

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soluble silver chloride by mixing solutions of silver nitrate and sodium chloride,

(I) $AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$

and the formation of two insoluble precipitates, silver chloride and barium sulfate, as illustrated by substituting barium chloride for the sodium chloride in equation (I) and silver sulfate for the silver nitrate,

(II) $Ag_2SO_4 + BaCl_2 \rightarrow 2AgCl + BaSO_4$

That something happens in these two cases is obvious. But even when no precipitate is formed an imaginary reaction has been supposed to occur, as when sodium nitrate and potassium chloride solutions are mixed. This has been written

(III) $NaNO_3 + KCl \rightarrow NaCl + KNO_3$

and has been widely used for years.

The other most important kind of reaction that has been grouped with these is the neutralization reaction, for example

(IV) $NaOH + HCl \rightarrow NaCl + H_2O$

and we have characterized this by the formation of a slightly ionized substance rather than an insoluble one.

In addition to the above cases this category has been made to include complex ion formation and reactions at electrodes during electrolysis (Schlesinger, *General Chemistry*, 1930, p. 271), which seems to the writer to be like adding further burdens to an already broken down horse. At least this paper is an attempt to show that the double decomposition reaction is such.

The justification for the name "double decomposition," or "transposition," or the more high sounding synonym, "metathesis," has been the statement that the two substances written on the left in the equation both decompose. This statement assumes that *molecules* of these substances, which in most instances are strong electrolytes, really exist in the solution. This idea is greatly emphasized by the mistaken but unfortunately general custom of writing molecular formulas for strong electrolytes.

To a student in elementary chemistry it seems curiously inconsistent for his instructor to make such use of molecules and molecular formulas and then to tell him that nearly fifty years ago Arrhenius produced excellent evidence that most of the material in solution was present as ions rather than as molecules. In fact Arrhenius and his contemporaries had no evidence that any molecules were present. They simply found that a certain part of the substance did not show the activity that was characteristic of ions. It was, therefore, supposed that this part must be present as molecules. This explanation was very successful for weak electrolytes, the degree of ionization of which found quantitative expression in Ostwald's dilution law.

The assumption of the existence of molecules of strong electrolytes by the chemists of fifty years ago was a natural one. A particular importance was being attached to them in those days. It was less than thirty years since Cannizzaro had pointed out the use of molecular weights in the method of determining atomic weights. It was only nine years before Arrhenius proposed the ionic theory that Victor Meyer devised his vapor density method for determining molecular weights.

The fact that the Ostwald dilution law does not hold for strong electrolytes has been known for years, nevertheless, many chemists still continue to treat strong electrolytes qualitatively in the same way as they do weak electrolytes. Other evidence of this inconsistency is to be found in their failure to accept the implications of the constant heat of neutralization of strong acids and bases, and of Hess' law of thermoneutrality, which was discovered as early as 1841. The latter states that if two neutral salt solutions at the same temperature are mixed together, no change of temperature occurs. The theory of complete ionization is strikingly successful in explaining the reason for this. No temperature change means no reaction at the time of mixing. Consequently equation (III) does not represent the situation as it exists. The substances are ions and mixing ions does not necessarily produce a reaction. See equation V.

$$\text{(V)}\quad \overset{+}{\mathrm{Na}}+\overset{-}{\mathrm{NO_3}}+\overset{+}{\mathrm{K}}+\overset{-}{\mathrm{Cl}}\rightarrow\overset{+}{\mathrm{Na}}+\overset{-}{\mathrm{NO_3}}+\overset{+}{\mathrm{K}}+\overset{-}{\mathrm{Cl}}$$

The combination of the ions into the four possible kinds of crystals occurs only when the solution is evaporated to dryness. The difference from the cases shown in (I) and (II) is in degree of solubility only.

In recent years the conception of complete ionization of strong electrolytes has received practicaly conclusive verification from X-ray crystal analysis, which has been applied to the crystalline forms of many strong electrolytes and has shown that they are composed entirely of ions. There are no molecules distinguishable in the crystal. If such is the case then there certainly are none in a solution of the crystal, for the ions are then farther apart than they are in the crystal itself.

In 1923 Debye and Huckel contributed further to the cause of complete ionization when they proposed an interionic attraction theory to explain the behavior of strong electrolytes. It has done so very successfully. We need no longer be concerned about their failure to follow the Ostwald dilution law, which would postulate the presence of molecules. Neither do we need to suppose that molecules are present in strong electrolytes.

In conclusion the writer suggests that it is inaccurate, misleading, and a waste of time to use molecular formulas for strong electrolytes in any instance. The time-honored double decomposition reaction does not exist. In its place we have several different kinds of changes, for instance, crystallization when precipitates are formed, or a change from electrovalence to covalence in neutralization reactions. Complex ion formation is a matter of co-ordinate covalence, and electrolytic reactions are best considered as oxidation-reduction changes.

UNDERGROUND FEATURES OF SINKING CREEK, WASHINGTON COUNTY, INDIANA

ROBERT E. BATES, Indiana University

Sinking Creek is a small stream draining about twenty-five square miles in the southwestern part of Washington County. It flows into Blue River where the latter stream makes a big northward bend at the intersection of Washington, Harrison, and Crawford counties.

The region in which Sinking Creek lies is near the western margin of the general karst region of southern Indiana where the clastic Chester formations make high, rugged inter-stream areas between karst valleys developed in the Mississippian limestones. Numerous ravines, descending from the ridges, end in swallow-holes, forming numerous blind valleys which terminate in the valley areas. (See Fig. 1.) The ridges reach altitudes of 850 to 950 feet above sea level. The valleys in which the sink-holes occur range from 675 to 775 feet.

The first view of Sinking Creek is on the Patton farm near the old Sinking Creek church, in the middle of the N½ of the SE¼ of Sec. 15, T1N, R2E, where the roof of the underground channel has fallen in. The stream comes out of one side of the depression, flows fifty feet on the surface, and disappears in the other side.

The next place where the stream appears on the surface is at Craven's Spring in the NW¼ of the SE¼ of Sec. 34, T1N, R2E, where it issues from the limestone rock on the west side of the valley. The opening of this spring is about a foot and a half high and twenty feet wide and in time of flood is completely filled with water which appears to flow under considerable pressure. From this place the stream follows a surface channel for about a mile and three-quarters to a series of swallow-holes just north of U. S. Highway No. 150 about one-half of a mile east of Hardinsburg, in the SW¼ of the SW¼ of Sec. 2, T1S, R2E. Here it enters an underground conduit which it follows to within a quarter of a mile of Blue River, where it issues from a bluff of its old valley as a spring, known as the Radcliff Spring. The airline distance between these two points is about two miles. Part of the water of this underground stream, however, appears at the Mitchell Spring, which is about half-way between the sink and the rise. The water coming out of this cavernous opening at the Mitchell Spring flows over the surface for about 150 yards and disappears again into a series of swallow holes.

The most interesting physiographic feature of this area is the underground conduit through which the stream passes. The writer, with the aid of Dr. C. A. Malott, of Indiana University, was able to enter and map this conduit for a measured distance of 9,230 feet, which appears to be about one-half of its total length. By adopting this underground cavern the stream has abandoned a roundabout surface

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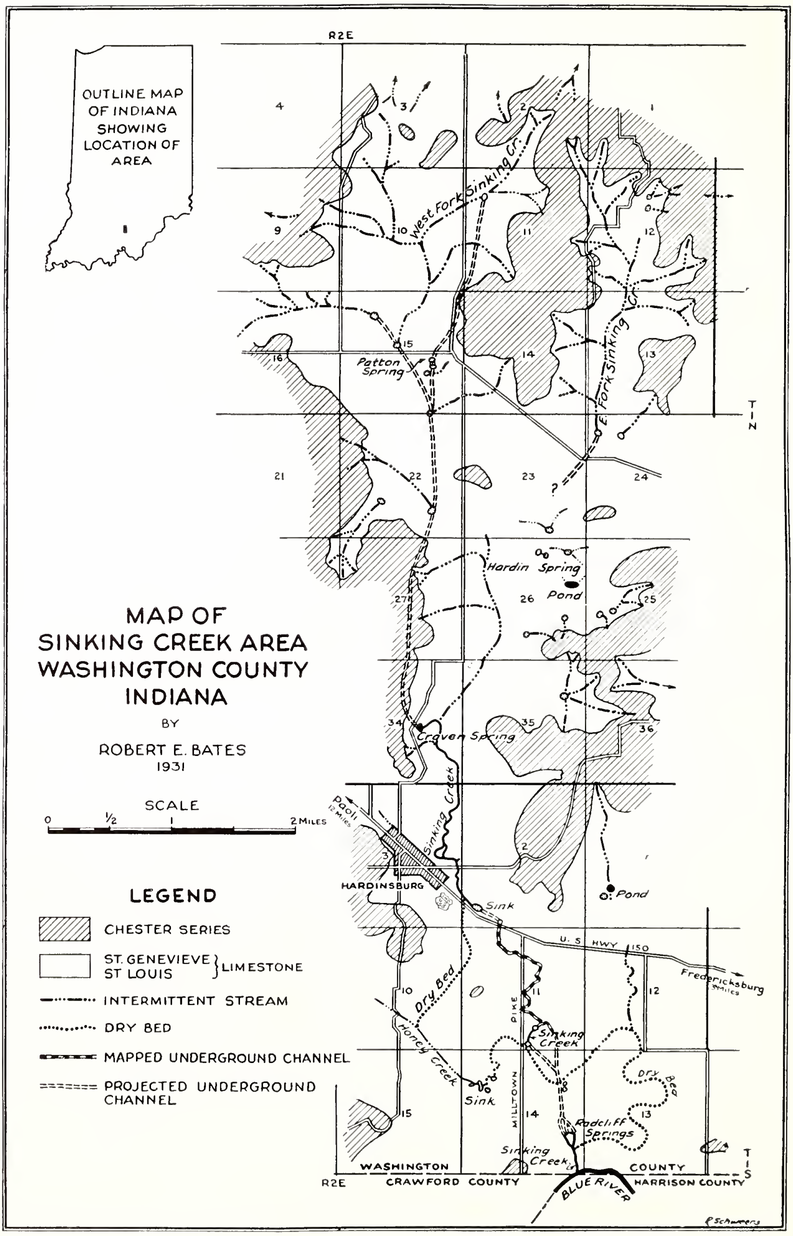
MAP OF
SINKING CREEK AREA
WASHINGTON COUNTY
INDIANA
BY
ROBERT E. BATES
1931
OUTLINE MAP OF INDIANA SHOWING LOCATION OF AREA
SCALE
0
½
1
2 MILES
LEGEND
CHESTER SERIES
ST. GENEVIEVE
ST LOUIS
LIMESTONE
INTERMITTENT STREAM
DRY BED
MAPPED UNDERGROUND CHANNEL
PROJECTED UNDERGROUND CHANNEL
R2E
T 1 N
T 1 S
West Fork Sinking Cr.
E. Fork Sinking Cr.
Patton Spring
Hardin Spring
Pond
Craven Spring
Sinking Creek
Paoli 12 Miles
HARDINSBURG
Sink
Pond
U. S. HWY 150
Fredericksburg 5 Miles
Dry Bed
Honey Creek
Sink
PIKE
MILLTOWN
Sinking Creek
Radcliff Springs
Sinking Creek
Dry Bed
WASHINGTON
COUNTY
CRAWFORD COUNTY
HARRISON COUNTY
BLUE RIVER
R. Schumers
4
3
2
1
9
10
11
12
16
15
14
13
21
22
23
24
?
27
26
25
34
35
36
3
2
10
11
12
15
14
13

Figure 1.

channel, about six miles in length, except in time of flood, when the underground channel is not large enough to take care of all of the water of the stream. At such times the excess water follows the old surface route.

Acting on information given us by an old resident, we entered a most inconspicuous and unassuming sink-hole which led us into this underground channel. The cavern may be said to consist of two parts, each one of which is characterized by an entirely different cross-section and appearance. One of these parts, comprising the upper 6,520 feet of the mapped channel, is significant because of its great regularity of cross-section, varying in width from twenty-five to thirty feet, or even forty or fifty feet on the turns, and in height from four to ten feet. This part of the conduit is in all places beautifully arched, and may be lined on one or both sides with banks of very tough mud, which is brought into the channel by the stream in time of flood. The second part of the cavern, consisting of the lower 2,710 feet, is much smaller than the first part, varying in width from six to twenty feet and in height from four to six feet. The roof of this part of the channel is not arched but flat, and the walls are vertical. The underground channel throughout its entire length appears to conform to two sets of joints, one having a northeast-southwest direction and the other a northwest-southeast direction.

The large room (indicated by A in Fig. 2) at the beginning of the mapped channel, about 4,535 feet from the entrance at B, is about eighty feet wide in an east-west direction and one hundred feet wide in a north-south direction. Small tributary streams flow into the room on the north and east sides but the main stream enters the room from under a low rock which touches the water on the west side, as an inverted siphon. From this pool the water flows between a high mud bank and the west wall into the main channel. The walls of this room between the inflowing streams are lined with banks of mud which settles out of the water that is ponded in the underground conduit when the channel is not large enough to allow the escape of flood waters. The mud, however, has been removed from the floor of the room by water subsequent to the flooding and has left a level gravel floor.

The channel between this room and the collapse feature at the cavern entrance is a portion of the first part of the cave mentioned above. In places where there are no abrupt turns, the channel has a typical cross-section as shown in Fig. 2, Cross-section 2. The mud may be banked on one or both sides, with the stream usually flowing in the center of the channel. In some places the stream is flowing in a trough of mud and in some places it flows on a gravel bed. Stalactites are found in zones scattered throughout the entire length of the channel. These zones correspond to a certain extent to the places where the underground conduit is nearer to the surface. On the turns the cross-section of the cavern is slightly different in that the stream follows the outside wall of the channel, thus cutting the channel deeper on the outside; and the mud is commonly found only on the inside of the turn.

The entrance to the channel (indicated by B in Fig. 2) is a collapsed portion of the roof of the underground channel. This collapse occurs at

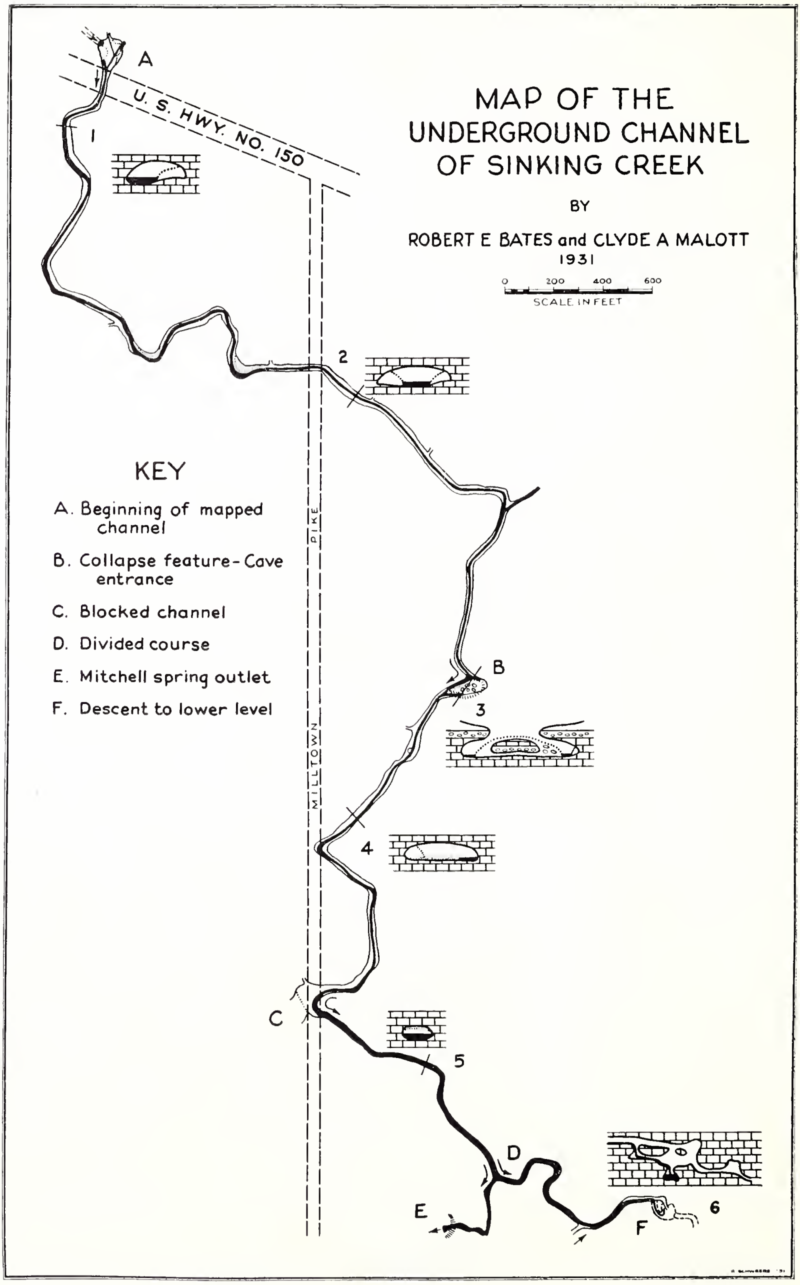
MAP OF THE
UNDERGROUND CHANNEL
OF SINKING CREEK
BY
ROBERT E BATES and CLYDE A MALOTT
1931
0 200 400 600
SCALE IN FEET
U. S. HWY. NO. 150
MILLTOWN PIKE
KEY
A. Beginning of mapped channel
B. Collapse feature-Cave entrance
C. Blocked channel
D. Divided course
E. Mitchell spring outlet
F. Descent to lower level
A
1
2
B
3
4
C
5
D
E
F
6

Figure 2.

a place where the stream in making an abrupt turn has greatly widened its channel. The water now passes on both sides of a large mass of the overlying strata which seems to have dropped into the channel as one huge block. This feature may well be considered to be an early stage in the development of a gulf. A great deal of mud has been deposited just above this obstruction because of the ponding of the water above this barrier in time of flood.

The channel between the collapse feature and the place indicated by C in Fig. 2, is in a general way similar to the channel above the collapse. The principal difference between the channel above and below the collapse is the fact that below the collapse there is a notable absence of mud for some distance. This may be explained by the fact that most of the mud carried by the stream settles out of the water while the water is ponded above the collapsed material, leaving little to be deposited immediately below it. Where there is an absence of mud the stream flows over a gravel floor. The roof of this part of the cavern is lined with numerous rope-like deposits of dripstone which are pure white in color and stand out beautifully against the muddy roof of the channel. As the stream approaches C, it is again ponded, and mud is found deposited in a manner similar to that above the collapse. It is an interesting fact that during the mapping of this channel between B and C, in two instances a noise resembling thunder or a car passing overhead was heard; and that when the channel was plotted both places at which the noise was heard coincided exactly with a road passing overhead. At another place in this part of the cave the pipe of a farmer's well passed through the cavern.

The blocked channel (indicated by C in Fig. 2) is of great importance from the standpoint of the development of the present underground channel of Sinking Creek. It now appears as a room about sixty feet wide east and west, the entire southwest side of which is a wall of mud. There is evidence that at one time the cavern continued in a southwest direction and came to the surface a short distance beyond the place where the wall is now silted up. There is a small tributary entering the north side of the room, and on the east is the channel by which the stream now leaves the room. The floor of the room is strewn with large pieces of rock which have fallen from the ceiling.

The channel below this room is of a very different type from that described above and makes up the second part of the conduit. The channel (as shown by Cross-section 5, in Fig. 2) is much smaller than the first part of the conduit. In this part of the channel the water is ponded from room C to within 250 feet of the Mitchell Spring outlet in one branch and almost to the end of the upper level in the other branch. From the ponding of the water for such a long distance and the great difference in the size and appearance of the two parts of the underground channel, it may be concluded that the greater part of that portion of the channel below room C was once a tributary channel entering the main channel at C, the main channel continuing at that time through the cavern which is now silted up. With the exception of a short distance near the Mitchell Spring outlet and a short distance at the end of the other branch of the stream, the water in that part of the channel below C flowed, as a tributary to the main stream, in the opposite direction to what it does at the present time. Throughout this part of the channel the roof is lined with countless small stalactites, the size of which may be explained by the fact that they are probably broken off in time of flood by the water which rushes through the conduit.

The channel divides at a point, indicated by D in Fig. 2, into two branches. One of these branches soon becomes a very small stream and after passing over a small ripple it follows a very crooked channel which comes to the surface at the Mitchell Spring. This part of the stream flows on the surface for about 150 yards and sinks into a series of swallow-holes leading to a lower subterranean channel. The other branch leading eastward from the forks of the channel is similar to that portion of the channel immediately above the forks. About 850 feet beyond the forks, however, there is a small ripple, and a number of potholes and openings leading to a lower level are found in the floor of the channel.

A short distance beyond this ripple the stream enters that part of the channel represented in Fig. 2 by the longitudinal cross-section 6. Here the stream in a series of falls drops some fifteen feet into a large room, which can also be reached by continuing in the upper level. It then drops another twelve feet into a circular pit about ten feet in diameter, from which the water leaves by an opening below the water level. Before reaching the place where it falls out of the upper level, the stream does not descend more than three feet in its entire underground channel, limiting itself to the same rock stratum throughout the whole distance.

This underground channel is cut in the basal portion of the St. Genevieve limestone, the Lost River chert occuring about fifteen feet above the stream level at both the collapse feature at B and at the Mitchell Spring. It might be said in explanation of the preceding statement that as a result of field work done during the summer and fall of 1931, Dr. C. A. Malott[1] has concluded that the division between the St. Louis and the St. Genevieve limestones in Indiana is not at the Lost River chert horizon but is at an unconformity which ranges from ten to twenty feet below the Lost River chert. He has observed this unconformity near a cave on the south bank of the Lost River on the Mather farm, in the SW corner of the SE¼ of the SE¼ of Sec. 33, T3N, R1W. As evidence in support of this conclusion he states that he has found oolitic beds and the fossil crinoid *Platocrinus penicillus*, a form thought to be restricted to the St. Genevieve, below the Lost River chert. He also states that in no place has he found *Lithostrotion canadense* and *L. proliferum* in or immediately below the chert horizon.

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[1] Personal communication.

A FAULT ALONG BRYANT'S CREEK, NORTHERN MONROE COUNTY

Richard Freed and Ronald Rogers, Indiana University

Introduction. This fault was noted during the summer of 1931, in connection with work on the Harrodsburg-Borden contact in northeastern Monroe County, for the State Geological Survey. The displacement is by no means confined to the vicinity of Bryant's Creek, but is best displayed at various places along its course. Up to the present time, the writers have done little work toward determining the exact structural conditions produced by the fault, but a fairly accurate determination of the line of movement has been made.

Although it has been generally known that there are certain structural irregularities in the area, apparently no detailed study had ever been made. Stockdale, in his recent publication on the Borden rocks of southern Indiana, mentioned the fault and drew it as an apparent extension of the Mt. Carmel (Unionville) Fault, on his general structural map.[1]

It is quite probable that the fault is connected with the Mt. Carmel fault farther to the south and east, but an accurate determination of the fault zone in the southeastern part of the area is practically impossible, as it lies in the broad, flat valley of Bean Blossom Creek.

Description of the Region. The fault lies in parts of Marion and Washington townships, northern Monroe County, T10N, R1E and R1W. The major portion of the land is included in the Morgan-Monroe Counties State Forest area.

The northern part is a well-dissected upland, with long divides and deep-cut ravines and stream valleys, while the broad, level valley of Bean Blossom Creek forms the southern boundary. The tops of the ridges have an elevation of 850 to 900 feet, while the streams have cut down to between 625 and 700 feet.

The Harrodsburg limestone is the highest formation, capping the higher ridges to a thickness of from 0 to 75 feet. This is underlain by the upper Borden rocks, named the Edwardsville Formation by Stockdale. There are no other formations exposed in the area.

It is primarily upon the position, dip and displacement of the Harrodsburg limestone that the determination of the fault line and its amount of throw has been based.

Position of the Fault. From the north, the fault enters Monroe County probably in the valley of Hacker's Creek, in the center of the north half of Section 1, Washington Township, one-fourth to one-half mile east of State Road 37. The trend here is probably south of south-

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[1] Stockdale, P. B. The Borden (Knobstone) Rocks of Southern Indiana. Ind. Dept. Conserv. Div. Geol., Publication no. 98, pp. 313, 315, plate 7, **1931.**

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

east, although accurate data is lacking. That it is present for some distance north into Morgan County is evidenced by low-lying beds of limestone three-fourths of a mile north of the county line. The displacement passes a short distance east of Road 37 in the west half of the southeast quarter of Section 1, where it enters the drainage area of Bryant's Creek. From here, it continues to somewhere near the boundary between Washington and Marion townships, Sections 12 and 7, the trend being 30 to 35 degrees east of south. At this point, a change of direction is noted, the direction becoming approximately 45 degrees east of south, the fault crossing the headwaters of Bryant's Creek at the center of the south half of Section 7, and continuing to the northwest quarter of Section 17, Marion Township. From this point on, evidence based on the position of the limestone is lacking, although signs of displacement can be noted in the Borden sandstones and shales in the beds of several tributary streams of Greasy Creek in Section 17 and the southwest corner of Section 16. The fault, however, may lie farther to the west, in the main valley of Greasy Creek, as shown by the alternate broken line on the map. If it continues, as it most likely does, in its general southeasterly direction, it probably connects with the Mt. Carmel fault in the vicinity of Fleener's Bridge over Bean Blossom Creek, in the northwest corner of Section 34.

Amount of Throw. The displacement is practically vertical, with the downthrow on the southwest. The rift zone, in several places, appears to be quite wide, with a suggestion of perhaps two stages of faulting. This feature was noted also, by Logan, along the Mt. Carmel fault in Lawrence County.[2] The total width of the zone of displacement appears, at several places, to vary from 25 to 50 feet, and may be as much as 100 feet at others.

The amount of throw probably varies from 75 to 125 feet. This conclusion has been reached by subtracting the elevations of the base of the Harrodsburg near the fault from the calculated normal elevation, and from the elevations of tops of several ridges on the upthrow side, which are capped with a few feet of Harrodsburg. The elevation of the Harrodsburg, using a normal dip of about 33 feet per mile, slightly south of west, should be between 870 and 900 feet along the fault. The actual elevations, however, range from 770 to 810 feet. The Harrodsburg-Borden contact has been found, in other localities, to be variable, and this fact may account, to some extent, at least, for the apparent differences in the amount of throw.

The base of the limestone, at distances varying from one-fourth to one-half mile back from the rift zone, is generally 15 to 20 feet lower than that nearest the line, giving evidence of some drag on the downthrown Harrodsburg.

Conditions in the Fault Zone. The actual rift, as displayed by exposures of the downfaulted Harrodsburg, is distinctly visible in a steep bluff along the main headwaters of Bryant's Creek, in the center of the south half of Section 7, Marion Township. Here the fairly massive

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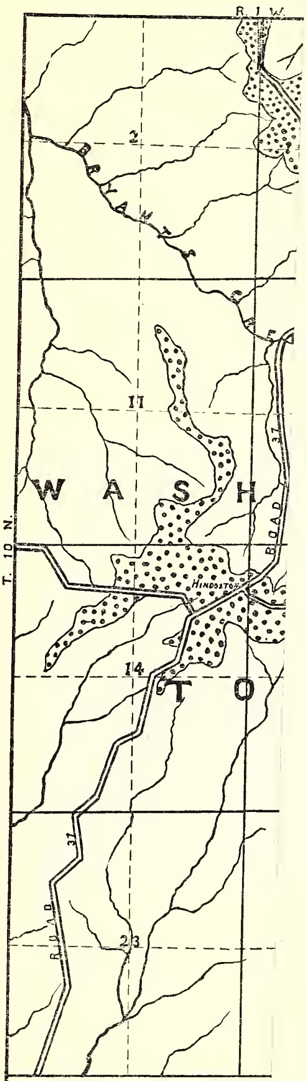
[2] Logan, W. N. Handbook of Indiana Geology, p. 840, 1922.



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R. Freed and
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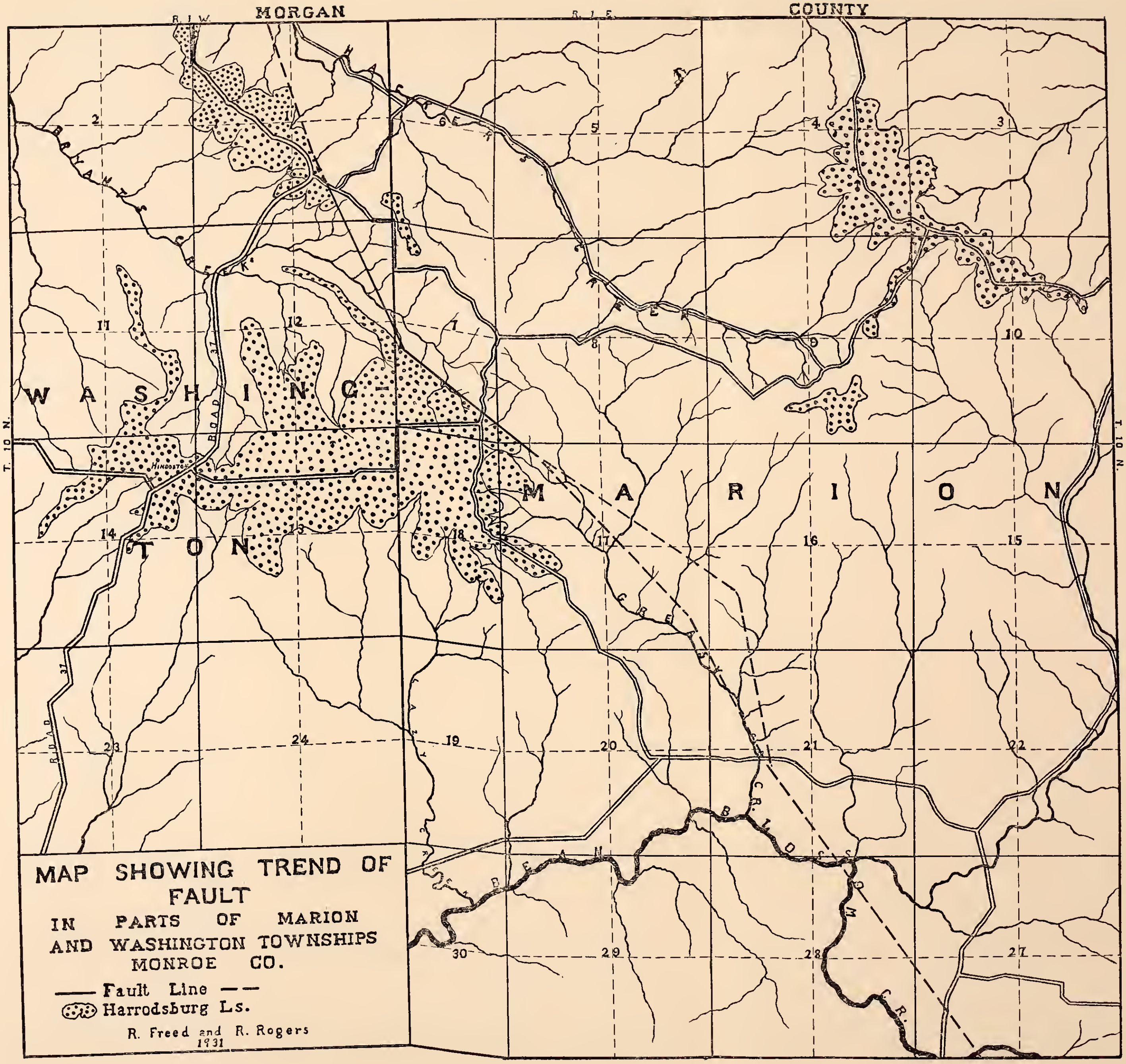
MORGAN
COUNTY
R. 1 W.
R. 1 E.
T. 10 N.
T. 10 N.
WASHINGTON
MARION
HINDOSTAN
ROAD 37
ROAD 37
BRYANTS CREEK
GREASY CR.
BEAN BLOSSOM CR.
1
2
3
4
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MAP SHOWING TREND OF FAULT
IN PARTS OF MARION
AND WASHINGTON TOWNSHIPS
MONROE CO.
Fault Line
Harrodsburg Ls.
R. Freed and R. Rogers
1931

Figure 1.

limestone is separated from the equally massive Borden sandstone by a fractured, weathered zone of both limestone and sandstone, about 15 feet in thickness. The Harrodsburg-Borden contact, seen in the stream bed 100 feet to the south, has an elevation of approximately 800 feet.

The above described section is the only one in which the actual fracture zone between Harrodsburg and Borden is visible, but in the southeast quarter of Section 1, Washington Township, the location can be determined to within about 100 feet. A gully extends south from a secondary road, one-eighth mile southeast of State Road 37. The base of the Harrodsburg here is at 795 feet. Two hundred feet to the east, a second gully has been formed. Massive sandstone is exposed on the slopes leading to this latter ravine, at an elevation of at least 840 feet. Thus the fault is between the two ravines, trending in a north-northwesterly direction.

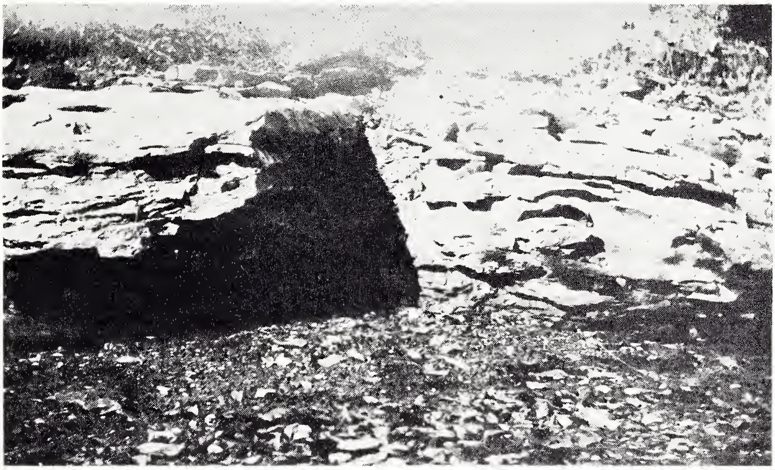


Fig. 2. Brecciated zone in bank of Bryant's Creek, east edge of Sec. 12, T10N, R1W, Washington Township.

Between the two localities just described, the fault apparently crosses Bryant's Creek at the eastern edge of Section 12, Washington Township. A weathered, brecciated zone, 16-18 inches across, is exposed in the creek bank. (See Fig. 2). Although it is hardly probable that the major fault surface is exposed at this point, slickensides were found, and some slipping must have taken place. The trend here is 32 degrees west of north. A sharp ravine, which enters the valley from the southeast, appears to occupy, for the most part, the fault zone.

Two small ravines in the southeastern part of Section 7, Marion Township, head in Borden sandstone and pass through several feet of limestone, showing that they have cut across the fault.

The base of the Harrodsburg in a ravine which extends toward the southeast, in the northwest corner of Section 17, is at 790 feet. A tributary ravine, entering from the north a short distance below the contact, passes through nothing but sandstone, although it heads in a divide which has an elevation of 865 feet. The location of the fault zone is evidently near the junction of the two ravines.

Other Features Associated with the Fault. An interesting feature present near the displacement is a series of sinkholes in the southern half of Section 7, Marion Township. Similar conditions have been reported from the vicinity of the Mt. Carmel Fault in Lawrence County. The sinks are developed in the limestone, about 50 feet from the zone of displacement.

Another feature, which suggests partial control of drainage by the fracture zone, is seen in the northeast quarter of Section 12, Washington Township. Three ravines within a distance of approximately three-eighths of a mile, heading in a southwesterly direction, have their courses abruptly changed to the northwest for a distance of from 100 to 200 feet, after which they again abruptly resume their original direction. It is quite possible that, due to the more easily eroded material in the fracture zone, the drainage turned and followed it for a short distance.

There appear to be many tension cracks and joints produced by the movement in the Borden sandstones and shales exposed in the beds of many streams in the area. These were little used as criteria, however, as this formation is easily susceptible to jointing and associated features produced by its variable character and composition, which may prove very deceptive to one not well acquainted with it.

The writers believe that interesting structural features are present on the downthrow side of the fault, due to the apparently irregular amount of displacement, and future work may disclose several minor anticlinal structures, such as the present farther to the south in Monroe and in Lawrence counties.

STRATIGRAPHICAL AND STRUCTURAL CONDITIONS IN THE SIOSI OIL FIELD

WILLIAM N. LOGAN, Indiana University

Location. The Siosi oil field is located near the Wabash River and approximately twenty-two miles southwest of Terre Haute. The field lies partly in Fairbanks Township of Sullivan County and partly in Prairie Township in Vigo County. The producing area lies in Sections 31 and 32 and in Sections 5 and 6. The nearest producing area, from Pennsylvania strata, lies in the southeastern part of Fairbanks Township. The nearest producing area from Devonian strata was the Riley field which is now abandoned.

Relief. The surface along the Vigo-Sullivan boundary line descends within the field from an elevation of 525 feet above sea level on the east to an elevation of 446 feet above sea at the Scott No. 4 well on the west side of the field. For the most part the surface of the field slopes westward with a low gradient toward the Wabash River. The elevation of the highest producing well is 525 feet above sea and the elevation of the lowest producing well is 446 feet above sea. During the flood stages of the Wabash River a part of the field is inundated.

Geology. The geological formations exposed at the surface in the Siosi field are of Recent and Pleistocene age. Beneath the surficial formations occur rocks which belong to Pennsylvanian, Mississippian, Devonian and Silurian periods of geological time.

Pleistocene and Post-Pleistocene Formations. Formations which belong to these two epochs cover the surface of the area. They consist of soils, clays, sands and gravels. Dune-like hills of sand have been formed along the border of the bottom lands. The thickness of these formations varies from a few feet to as much as one hundred feet. Some of the wells record a thickness of 85 feet of gravel at the base of the Pleistocene.

The Pennsylvanian Formations. Three divisions of the Pennsylvanian are represented in the field, viz: Post-Allegheny, Allegheny, and Pottsville. The formations of the series consist of sandstones, shales, thin limestones and intercalated beds of coal. Over a large part of the area there are at least three beds of minable coal. The maximum thickness of the coal is seven feet and the average of three beds is more than five feet. The total thickness of the Pennsylvanian sediments in the area ranges from 800 to 900 feet. Differences in thickness are due to pre-Pennsylvanian erosion which left an irregular surface on which the Pennsylvanian sediments were deposited. The contact of the Pennsylvanian with the underlying Mississippian cannot always be determinded since shales of the younger formation may rest upon shales of the older or sandstones of the younger upon sandstones of the older.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

The Pennsylvanian formations have produced some gas in the Siosi area, but no commercial supplies of petroleum have been found in its formation, although about six miles away toward the south strata of that age have produced petroleum in commercial quantities.

A TYPICAL PENNSYLVANIAN SECTION

The following section represents the geological formations and their thicknesses as they have been encountered in wells drilled in the field.

Shale, blue, plastic	50 feet.
Coal	5 feet.
Shale, light gray	95 feet.
Coal	5 feet.
Shale, gray	75 feet.
Shale, black	5 feet.
Coal	7 feet.
Shale, blue	150 feet.
Shale, limey	5 feet.
Sand, soft	140 feet.
Shale, blue	95 feet.
Sand	45 feet.
Shale	70 feet.

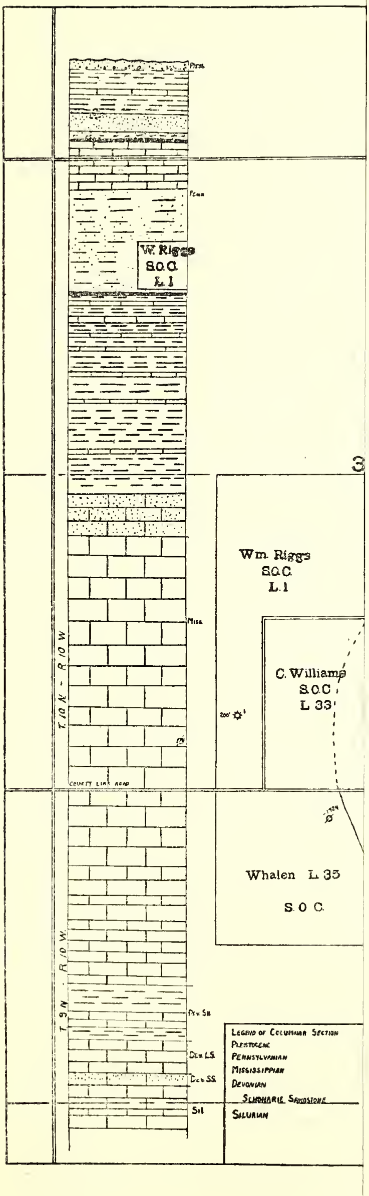
The Chester Formations. Beneath the Pottsville series in the Siosi field there is a group of formations consisting of limestones, shales, and sandstones which are assigned to the Chester division of the Mississippian period. The thickness of the group within the area varies from 75 to 150 feet. Interpretations based on some of the logs of the wells might serve to increase the range in thickness.

Small quantities of gas and some indications of oil have been reported from some of the limestones and sandstones of the group but no commercial quantities of either substance have been produced in the Siosi field from Chester formations. In other parts of Indiana, notably in the southwestern part, a large number of petroliferous horizons have been found in Chester formations. The porosity of the Chester sandstones aids in the circulation of petroleum and water where structural conditions are favorable.

CHESTER SECTION

A study of the well logs of the area indicates that the following formations of the Chester are present:

Blue shale, hard	10 feet.
Sand, hard, gray	15 feet.
Limestone, gray, broken	10 feet.
Limestone, hard	5 feet.
Shale, soft, green	10 feet.
Limestone	20 feet.
Shale	10 feet.


Prm.
Penn
W. Riggs
S.O.C.
L.1
Miss
T.10 N - R.10 W
Wm. Riggs
S.O.C.
L.1
3
C. Williams
S.O.C.
L 33
200'
1924
County Line Road
Whalen L. 35
S.O.C.
T.9 N - R.10 W.
Dev. Sh
Dev. LS.
Dev. SS.
Sil
Legend of Columnar Section
Pleistocene
Pennsylvanian
Mississippian
Devonian
Schoharie Sandstone
Silurian

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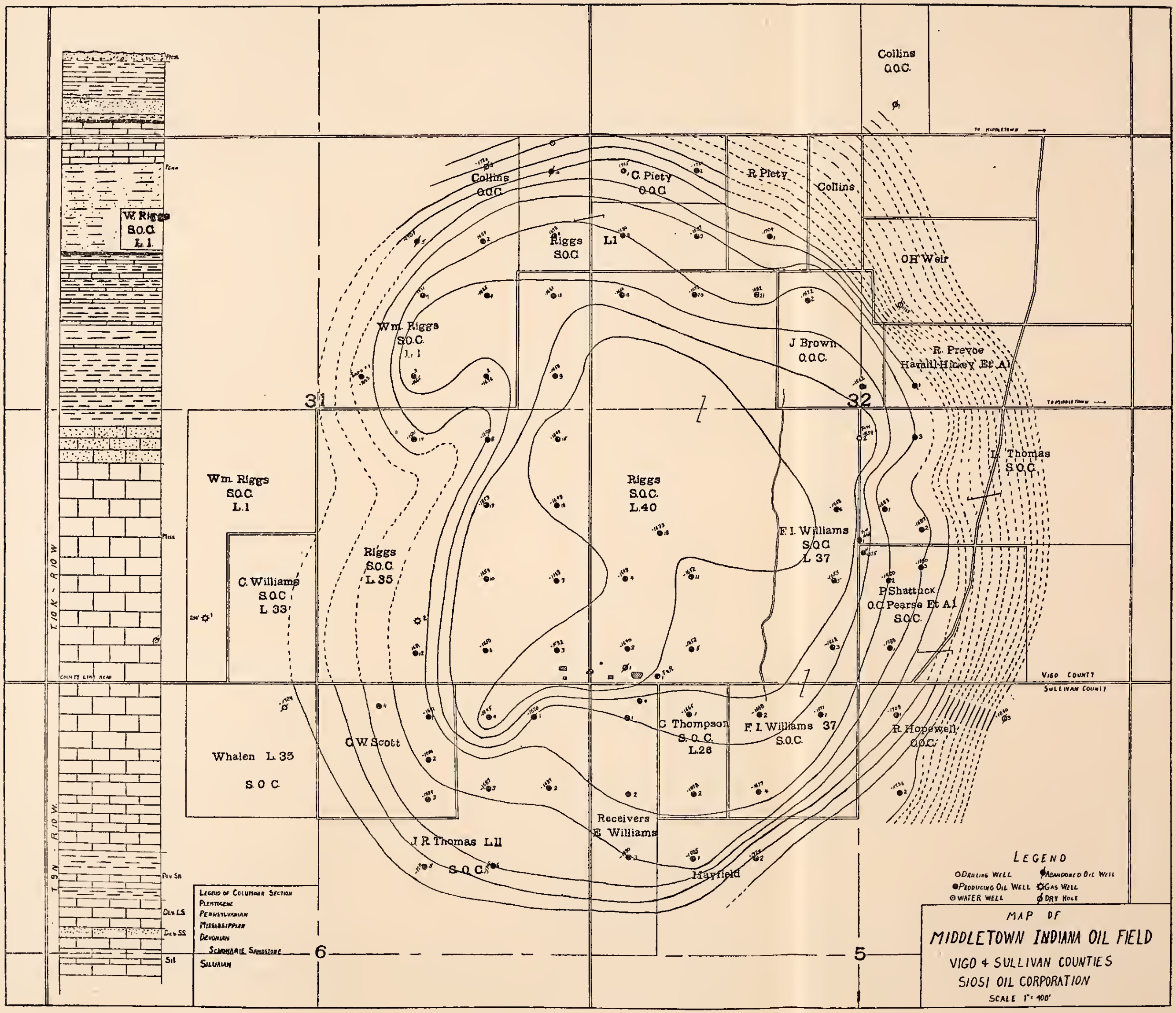
Collins O.O.C.
TO MIDDLETOWN
Collins O.O.C.
C. Piety O.O.C.
R. Piety
Collins
W. Riggs S.O.C. L.1
Riggs S.O.C.
L1
OH Weir
Wm. Riggs S.O.C. L.1
J Brown O.O.C.
R. Prevoe
Hamill-Hickey Et Al
31
32
TO MIDDLETOWN
L. Thomas S.O.C.
Wm. Riggs S.O.C. L.1
Riggs S.O.C. L.40
F. I. Williams S.O.C. L 37
Riggs S.O.C. L 35
C. Williams S.O.C. L 33
P Shattuck
O.C. Pearse Et Al S.O.C.
COUNTY LINE ROAD
VIGO COUNTY
SULLIVAN COUNTY
T. 10 N. - R 10 W.
T. 9 N. - R 10 W.
Penn
Miss
Dev Sh
Dev LS
Dev SS
Sil
Whalen L 35 S.O.C.
C.W. Scott
C Thompson S.O.C. L.26
F. I. Williams 37 S.O.C.
R. Hopewell O.O.C.
Receivers E Williams
J R Thomas L11 S.O.C.
Mayfield
6
5
Legend of Columnar Section
Pleistocene
Pennsylvanian
Mississippian
Devonian
Schoharie Sandstone
Silurian
Legend
○ Drilling Well
● Producing Oil Well
⊙ Water Well
Abandoned Oil Well
☼ Gas Well
ϕ Dry Hole
MAP OF
MIDDLETOWN INDIANA OIL FIELD
VIGO & SULLIVAN COUNTIES
SIOSI OIL CORPORATION
SCALE 1" = 400'

Only the members of the lower Chester group appear to be present in the Siosi area. The Paoli, the Mooretown, the Beaver Bend, the Sample, the Reelsville and the Elwren are probably present because these formations have been identified in outcrops northeast of the Siosi area.

Older Mississippian Formations. The formations older than the Paoli which are present in the Siosi field include the St. Genevieve, St. Louis, Salem and Harrodsburg limestones. The term "Big Lime" as used by the drillers in the Siosi field includes the Paoli limestones and all the limestones named above. Since the upper part of the Borden formation is highly calcareous it is often included in the "Big Lime". The formations consist essentially of white and gray limestones which are hard and cherty in some horizons, and granular and soft in others. In some parts of Indiana some of these limestones contain oil-bearing horizons but in the Siosi field they contain neither oil or gas in commercial quantities.

Borden Formation. In some parts of the Siosi field the upper part of the Borden formation is marked by the presence of a thin bed of shale. The upper part of the Borden is generally calcareous and is often classed as limestone by the driller. A microscopic examination of the drillings from some wells will reveal the presence of flakes of shale and sand grains. No petroleum was found in the Borden in the Siosi field but small quantities of gas occur in some horizons.

Kinderhook Formations. The Kinderhook formations include the Rockford (Goniatite) limestone member and some associated shales and sandstones. The group usually consists of an upper sandstone member which is called the Carper sand and which has been found to be an oil producing horizon in Illinois. Beneath the Carper is a thin shale member which is gray or green in color and rests upon a thin limestone (Rockford). A green colored shale lies below the Rockford and rests upon the surface of the New Albany shale. From fossil evidence collected in other areas it is probable that the green shale overlying the New Albany shale is of Devonian age.

The Devonian Formations. Beneath the Kinderhook limestone in the Siosi field there are four formations of Devonian age. In the western part of Indiana these formations are called the New Albany shale, the Sellersburg limestone, the Jeffersonville limestone, and the Pendleton sandstone of Schoharie age.

New Albany Shale. A dark colored kerogen bearing shale which is often called "Cinnamon shale" by the drillers is present throughout the Siosi area. Some drillers limit the term "Cinnamon" to the lower part of the New Albany and call the upper part the black shale. The upper portion is in some places darker in color while the lower part is of a brown or cinnamon color. When examined in thin sections under the microscope the mineral matter which constitutes the larger portion of the shale is seen to contain particles of resinous matter which are largely in the form of spores and spore cases. Upon the application of heat to the shale the resinous matter is converted into gas and a shale oil from which some of the products of petroleum can be obtained.

The New Albany shale in the Siosi field ranges from 95 to 125 feet in thickness. It contains small quantities of gas, but is not a commercial gas-producing horizon such as that of the Laconia field in Harrison County. By using the upper surface of the New Albany shale as a key horizon a domelike structure is revealed. This structure does not differ materially from the one produced when the top of the Sellersburg limestone is used as a key horizon.

The Devonian Limestones. The Sellersburg limestone lies just beneath the New Albany shale in the Siosi field. It is a bluish-gray limestone which is somewhat shaly in its upper portion and is very porous. It forms an oil-producing horizon in the Siosi field and in the Riley field. It is thought to be of Hamilton age.

The Jeffersonville limestone lies below the Sellersburg. When seen in exposures it is a gray, crystalline limestone, occurring in thick layers, and extremely fossiliferous in certain horizons. The thickness of the formation in the Siosi field ranges from twenty to thirty feet. It is not petriliferous in this area.

The Jeffersonville limestone is considered of Onondaga age.

The Pendleton Sandstone. Below the Jeffersonville limestone in the Siosi field there is a calcareous, granular formation which in many places is a true quartz sand, but which in other places should be classed as a sandy limestone. The formation usually has a very open texture and contains many well-rounded quartz grains. It contains large quantities of gas and oil in the Siosi field. Wells drilled into this sand have been known to flow for several days under the gas pressure. Many of the earlier wells which were drilled reached only the Sellersburg producing-horizon, but many of these wells have been deepened to the Pendleton sand and a larger production obtained. The thickness of the sand varies from a few feet to thirty feet.

Silurian Limestones. A series of limestones of Silurian age lie below the last mentioned formation. In some horizons these limestones are very porous and where the proper structural conditions were present they have been productive petroleum horizons.

GEOLOGICAL FORMATIONS OF THE FIELD

Post-Pleistocene—soils, sands and clays.
Pleistocene formations—clays, sands and gravels.

Pennsylvanian formations—
    Post-Allegheny formations—shales, coals, sandstones.
    Allegheny formations—sandstones, shales, limestones and coals.
    Pottsville formations—shales, sandstones, coals, clays.

Mississippian formations—
    Chester formations—shales, limestones and sandstones.
    St. Genevieve formations—limestones.
    St. Louis formations—limestones.
    Salem formations—limestones.
    Harrodsburg formations—limestones.
    Borden formation—shales, silts and limestones.
    Rockford formation—limestone.

Devonian formations—
New Albany formation—shale.
Sellersburg formation—limestone.
Jeffersonville formation—limestone.
Pendleton formation—sandstone.
Silurian formations—limestones.

THE STRUCTURAL MAP

The structural conditions, so far as they can be determined from data now in hand, are outlined on the accompanying map. The key horizon used is the upper surface of the Sellersburg limestone.

As may be seen from the accompanying map, in which the contour interval used has a value of ten feet, the surface of the key horizon descends from an elevation of —1639, the highest point, to an elevation of —1840 in a southeasterly direction, to a similar elevation in a northeasterly direction, to an elevation of —1730 in a northwesterly direction and to an elevation of —1720 in a southwesterly direction. Drilling operations have outlined the structure fairly well. If there are any minor structures on the borders of the main structure such have not been encountered by the drill.

TYPICAL WELL LOGS FROM THE SIOSI FIELD

Log of well No. 5 in Section 32, T. 10 N, R. 10 W. Drilled by the Siosi Oil Corporation. Completed in December, 1927. Elevation 470 feet.

Formations	Feet	Feet	
Soil		6	Recent
Shale	9	15	Pennsylvanian
Limestone	15	20	
Shale	20	80	
Limestone	80	83	
Shale	83	90	
Sandstone	90	100	
Shale	100	410	
Sandstone	410	440	
Shale	440	485	
Sandstone	485	515	
Shale	515	560	
Sandstone	560	580	
Shale	580	585	
Limestone	585	590	
Shale	590	650	
Sandstone	650	710	
Shale	710	725	
Sandstone	725	763	
Shale	763	885	
Sandstone	885	925	
Shale	925	950	Chester
Shale	950	975	
Sandstone	975	995	
Shale	995	1005	
Sandstone	1005	1040	

Formations	Feet	Feet	
Limestone	1040	1885	St. Genevieve St. Louis Salem, Harrodsburg
Shale	1885	1965	Borden
Sandstone	1965	1985	
Shale	1985	2000	
Limestone	2000	2005	Kinderhook
Shale	2005	2085	New Albany
Shale	2085	2125	
Limestone	2125	2162	Sellersburg
Oil at	2133		

Initial production 60 barrels in 24 hours.

Log of well No. 13 in Section 31, T 10 N, R10 W, drilled by the Siosi Oil Corporation, completed in July 1928. Elevation, 450.5.

Formation	Feet	Feet	
Gravel		84	Pleistocene
Shale, soft	84	90	Pennsylvanian
Sandstone	90	120	
Shale	120	315	
Limestone	315	320	
Shale	320	330	
Sandstone	330	375	
Shale	375	450	
Sandstone	450	485	
Shale	485	650	
Sandstone	650	660	
Shale	660	705	
Sandstone	705	750	
Shale	750	860	
Sandstone	860	885	
Shale	885	930	Chester
Sandstone	930	950	
Shale	950	960	
Limestone	960	975	
Sandstone	975	1040	St. Genevieve St. Louis Salem Harrodsburg
Limestone	1040	1870	
Shale	1870	1935	Borden
Sandstone	1935	1950	
Shale	1950	1975	
Sandstone	1975	1990	
Shale	1990	2112	New Albany
Limestone	2112	2199	Sellersburg Jeffersonville

Initial production 130 barrels.

Number of Wells on Leases

Hopewell Lease	3 wells
F. I. Williams Lease	6 wells
Shattuck Lease	4 wells
L. Thomas Lease	3 wells
Thomas and Williams (line wells)	2 wells
Prevoe Lease	1 well
Weir Lease	1 well
Collins Lease	3 wells
Riggs Lease No. 1	7 wells
Riggs Lease No. 35	10 wells
Riggs Lease No. 40	7 wells
C. Thompson Lease No. 28	2 wells
Mayfield Lease	2 wells
E. Williams Lease	4 wells
J. Thomas Lease	6 wells
Whalen Lease	1 well

DAILY PRODUCTION IN BARRELS OF SOME OF THE WELLS IN THE SIOSI FIELD

Day	Wells															
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	52		20	25	64	57	49	59	40	37	33	30	13	21	29	32
2	46	54	14	21	50	58	55	57	39	57	24	20	33	32	77	45
3	20	56	21	22	71	55	67	50	46	63	29	28	24	35	32	31
4	49	50	21	23	52	57	57	12	86	86	29		24	32	29	36
5	55	40	18	24	44	52	52	47	39	59		44	26	36	34	45
6	48	40	30	22	39	10	56	50	39	68	57	90	24	38	35	50
7	49	90	15	22	54	33	61	54	32	51	32	37	24	36	39	37
8	48	34	16	20	39	52	50	51	37	65	24	25	20	22	23	28
9	54	38	16	24	42	55	54	49			25	16	35	26	36	26
10	47			11		54	37	56		39	14	14	12		30	35
11	53	33	16	20	39	52	50	51	34	65	27	21	23	31	33	
12	51	29	16	26	50	49	55	45	79	63	27	25	25	39		39
13	51	41	17	22	49	52	53	40	71	27	36	20	27	31	32	25
14	53	41	15	28	42	47	12	53	38	49	37	40	35	35	20	34
15	49	39		24	42	54	50	55	40	71	23	48	21	31	29	30
16	51	43		24	21	51	45	53	38	58	20	39	50	30	36	39
17	52	39		22	57	51	50	57	40	56	28	31	22	31	32	41
18	48	41			47	54	54	49	48		18		20	31	27	30
19	49	39		19	50	44	54	53	38	49	22	51	20	19	30	26
20	51	36		27	28	53	48	54	31	51	30	46	20	20	35	10
21	47	34		26	55	53	56	49	33	53		48	21	35	32	30
22	47	38		15	36	55	34	52	35	59			20	31	28	32
Total.....	1070	855	235	467	971	1098	1099	1096	883	1126	535	673	539	642	698	701

The writer is indebted to Mr. A. F. Lager, Superintendent of the Siosi Corporation and to the following members of his field party in 1931: Paul Kerr, Maurice Felgar, Rex Rader, Courtney Boone, Ronald Rogers, and Thomas Mooney.

EXPERIMENTS IN MODEL MAP MAKING

A. H. MEYER, Valparaiso University

A. The Model. Expressions of relief by contour lines as featured on topographic maps is, and perhaps ever will be, the most valuable contribution to the art of relief mapping. When to this feature, as Major Roberts points out, is added a superimposed "high light photograph of an accurate relief model on a contoured base of the same area, a contoured map with the addition of an apparent third dimension results" especially helpful to "commercial firms and designers of engineering projects."[1]

The converse of this principle as applied to relief modeling seems to the writer to be equally true. The superposition of contour lines on the bas relief assists in forming the relative altitude perspective, and, in special cases at least, continuous line data seem quite essential in elucidating relationships of physiographical, structural, and historical geology phenomena.

It occurs to the writer, then, that in the making of a single local laboratory relief model by the conventional method of superimposing layers of cardboard or other material cut to conform to successive contours, a mistake is made in the modeling process of covering up the edges of the successive layers which might well serve as contour lines on the finished model.

The object of the present experiment was to bring out this contour feature on a relief model, and otherwise to elaborate on as many details as could well be shown to make the model a truly instructive device of the laboratory instead of just another mural decorative fixture.

The technique of model construction in current usage is excellently detailed and illustrated by Major Roberts.[2] Methods employing apparatus for modeling are reported which appear to expedite matters very much and, it is hoped, may lend themselves to incorporating the contour feature on commercial models.[3] [4]

The writer's model was constructed without the aid of any special apparatus, a process admittedly very time-consuming. Tracing and cutting of cardboard along contour lines was participated in by the class in Physiography. A dark red cardboard was used to make the contours more conspicuous. Following this, the layers were successively mounted with glue, and the whole unit securely affixed by means of screws to a baseboard.

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[1] Roberts, L. B., "Topographic Mapping." The Society of American Military Engineers, p. 63, 1924.

[2] Op. cit., pp. 63-70.

[3] Gradenwitz, Alfred, "Quantity Production of Relief Maps." Scientific American, March, 1922, p. 178.

[4] Holmes, Chauncey D., "A Method of Making Topographic Models." Science, 73:368-369, 1931.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

The mounting completed, the next step was to find a suitable molding substance. Several, including plaster paris, were tried with more or less indifferent results. The present situations calls for a molding material which applies readily, smoothly and securely; sets sufficiently slow to allow for fashioning; adhering well enough to the cardboard; and upon hardening presenting a reasonably hard, smooth and preferably white finish. Perhaps the most important quality is a tenacity of adherence on account of the interrupted molded surface. Everything considered, "rough coat plaster," as it is known in the builder's trade, seems to satisfy the requirements best.

The molding finished and smoothed, the contour model is now ready for coloring to show drainage and areal geology features. Precaution is necessary to apply the tints very lightly so as not to obscure the contour lines.

Lettering, or labelling, was tediously but neatly done by means of single solid rubber type, two styles of fonts being used. Finally, a coat of shellac was applied to bring out both the print and the contour lines, besides imparting luster and finish to the surface.

Considerable expenditure of time being involved in the construction of a model of the above type, it behooves one to select as a prototype area to be modeled a region abounding in diversity of landscape forms and geologic phenomena, preferably a region in which field trips are regularly conducted, thereby stimulating sustained interest in field studies.

The prototype of the present model is the Calumet, Illinois-Indiana, quadrangle, which as far as the writer is aware, has not previously been modeled, except on a very general scale as part of a much larger landscape unit. The region, as part of the greater Chicago area, affords a rather unusual combination of geologic-geographic phenomena. Red rock exposures are featured by the extensive limestone quarry of the Brownwell Improvement Company at Thornton, the largest quarry in the state of Illinois, and in the abandoned quarry at Stony Island, both famed for their coral reef structures of the Niagaran rock system. Physiographic phenomena include the Valparaiso Moraine and the Chicago lake plan with its three epochal and other minor shore line beaches partly modified into minature dunes, together with three conspicuous lake plain islands, and the associated historically interesting drainage phenomena of the Sag outlet and the Calumet River. In this quadrangle contour lines take on a peculiar significance in their relation to the position and elevation of the "fossil" beaches and islands of the ancient lake plain.

The cultural features are typical of a region tributary to a metropolitan commercial and industrial center, partly evidenced by the convergence of the railroads and the arterial highways, exhibiting the influence of the southerly extension of Lake Michigan.

B. The Map. The second experiment involves an enlargement and elaboration of Lobeck's well known Physiographic Diagram of Europe. This diagram together with that of the United States by the same author, it will be recalled, employ a physiographic symbolism scenically expressive of types of rock structure and land forms.

The present cartographic project grew out of a desire for a wall size reproduction of Lobeck's Diagram of Europe presently available only in desk copy size (18" x 23"). It was desired, moreover, to have the map show complete labeling of the physiographic forms and provinces as enumerated and discussed by the author in the published text which accompanies the map, and finally, to utilize this base for representing comprehensively all the essential types of mappable geographic phenomena consistent with legibility, whether physical or cultural, thus bringing into juxtaposition and superposition all the essential geographic factors in their proper setting and relationships, results not so readily realized where a separate map must be consulted for each class of geographic data, and these perhaps on different scales. Thus one map of a continent may show relief, a second political boundaries, a third climatic phenomena, a fourth economic features, etc.

Granting that it may not be possible, or even practicable, to attempt to show on one map all geographic data, the viewpoint is taken that one wall map large enough to accommodate most of the essential material is worth more than many scattered smaller maps with varying scales.

With this basic unification and correlation principle in mind, the writer, with the assistance of the students in Geography of Europe, set out first to enlarge the diagram referred to. This was done by dark room projection onto a screen consisting of the paper on which the wall map was to be drawn. The bare major physiographic outlines as projected were then hastily traced in pencil, the work being done in sections.

The tracing of the projection completed, the next step consisted in revising or refining the outlines, and reproducing in ink the details of the diagram, whereupon the sections were ready for trimming, matching, and finally mounting on muslin.

Next, political boundaries were drawn in, and the countries set off in colors. This latter feature was accomplished by cutting out a paper stencil for each country, using this as a mat while subjecting each country in turn to a spray of transparent water color. Such colors should be of the lightest tints and applied with the finest spray possible to guard against obscuring the previously sketched physiographic details. The spray thus properly applied produces pleasing streak-free color effects comparing very favorably in this respect with commercial products of map publishers.[5]

The geologic section of Lobeck's diagram was reproduced at the bottom of the map. Climatic regions are set off by numerals and boundary lines in green according to nomenclature found in Regional Geography by Preston E. James (1929).

Labelling or printing was done by means of solid rubber type, several sizes and styles of fonts, and colors being used to further differentiate the various classes of map data. These entries were left largely for the student to supply, thereby affording an opportunity to build up a correlation background of the course material.

To extend the comprehensiveness of the chart, one-half of Lobeck's text was mounted on either side, and these together with the map framed by a series of specially selected type illustrations from the National Geographic Magazine. Thus we have a synthetic panorama representing a composite unit of geologic, physiographic, climatic, political, and cultural features, leaving economic data still to be supplied by a later class.

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[5] The sprayer used is of the adjustment type, manufactured by the G. V. Sprayer Co., Wichita, Kansas.

The size of the chart is 11 feet 3 inches by 6 feet 4 inches, the map itself being 7 feet 7 inches by 6 feet.

ACKNOWLEDGMENT

The author gratefully acknowledges the services participating students have rendered in these two projects. Particularly is he indebted to Messrs. H. O. Heinecke, E. W. Schaare, and L. D. Schramm for their contributions to the Panorama of Europe. In the coloring of the latter, valuable suggestions were received from C. O. Anderson, instructor in the Fine Arts Department of Valparaiso University.

LOST RIVER AT WESLEY CHAPEL GULF, ORANGE COUNTY, INDIANA[1]

Clyde A. Malott, Indiana University

Introduction. It is the purpose of this paper to describe the Wesley Chapel Gulf of Lost River and those parts of underground Lost River which are accessible in and near this gulf. The locality is in western Orange County, Indiana, about five miles southwest of Orleans and about two miles east of the village of Orangeville. The locality is near the western margin of the karst belt developed in the Mississippian limestones in southern Indiana. Undoubtedly the Wesley Chapel gulf and the rise and sink of underground Lost River within it, constitute one of the most interesting individual features in the Lost River karst area. The underground system of Lost River, accessible through an opening in the western wall of the gulf, is a system of unusual interest because its characteristics are largely unknown. A greater section of the underground system has been mapped in detail here than at any other place. The Wesley Chapel gulf and the accessible parts of underground Lost River have never before received an adequate description, nor have their characteristics as features of karst been fully set forth. It is advisable, however, to give the general setting of these features before entering into their detailed description.

Definition of Karst. The term *karst* is a comprehensive topographic term applied to limestone areas which possess a topography peculiar to and dependent upon underground solution and the diversion of surface waters to underground routes. The term is taken from the name of a narrow strip of a limestone plateau in Jugo-Slavia bordering the Adriatic Sea, where occurs a remarkable assembly of features dependent upon subsurface solution. The Karst or Carso plateau itself is composed of a number of geological formations both of Mesozoic and Cenozoic ages, but it is dominated by massive limestone beds. The formations have been gently folded and severely faulted. The structures and the relatively great relief of the Karst plateau and adjacent regions have greatly influenced the development of the features dependent upon underground solution and underground drainage, and the region possesses some rather unusual and unique features. The region, therefore, is somewhat special, and it does not serve as well for a type region for the features dependent upon subterranean solution and underground stream diversion as would a more simple limestone region of moderate relief. Perhaps the low limestone plateaus of the middle Mississippi valley region, in which are exposed the well bedded and nearly horizontal limestones of Mississippian age, present a more normal assembly of

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[1] Waterman Foundation, Indiana University. Contribution No. 59. 1931.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

features dependent upon underground solution and diversion of surface waters into cavernous routes.

Karst Areas of the Middle Mississippi Valley Region. The areas occupied by the nearly horizontal Mississippian limestones in small parts of Tennessee, western Kentucky, southern Illinois, eastern Missouri, and southern Indiana, comprising an aggregate area of some seven or eight thousand square miles, constitute one of the most notable karst regions of the United States. The strata in which underground drainage is highly characteristic belong to the St. Louis and the St. Genevieve limestone formations. The Warsaw and Salem limestone formations below the St. Louis are much less subject to the development of underground drainage. The still lower Keokuk and Burlington limestones along the upper Mississippi River are subject to underground drainage, but the glacial drift has, except locally, masked or interfered with the karst features developed there. Certain of the Chester beds, above the St. Genevieve, have considerable development of underground drainage. The Chester, however, is typically constituted of alternating clastic and limestone formations, none of which reach any considerable thickness. The sandstone and shale beds in the Chester do not permit complete regional underground drainage development. The aggregate thickness of the limestone formations of the karst region is only a few hundred feet, ranging from about 300 to possibly 600 feet. Typically the strata composing the limestone formations of the general karst areas are relatively thin and the bedding planes are usually well developed. Shale beds are thin or wanting. The limestone beds are rather hard and dense. Some of the beds are conspicuously cherty. Usually two sets of intersecting joints are well developed.

In only a few places does the general karst region reach or exceed an altitude of 1,000 feet above sea level. Chiefly the karst areas range from 500 to 900 feet above sea level. The relief of the typically karst terrains is never great. It is nowhere more than a few hundred feet. Usually it is less than 200 feet. The limited relief does not permit the development of spectacularly deep karst features. For the most part the surface features are gentle rather than abrupt. Nearly everywhere the limestone formations in which the karst features are developed are covered with a relatively fertile reddish soil clothed with vegetation. Thus, the *terra rossa,* so prominently in sight in the Adriatic Karst, is little in evidence. It is, however, by no means lacking. Surface exposures and bedded limestone in relief are relatively rare, except along certain well intrenched major streams. The small relief of the limestone region, however, has not interfered with the development of complete underground drainage over fairly large areas. Areas as large as 100 square miles or more wholly without a surface stream are not uncommon. In such areas underground drainage is developed to the fullest extent possible. These areas of maximum underground drainage development characteristically possess a relief surprisingly small. Frequently it is less than 100 feet. They are veritable sinkhole plains.

Karst Features of the Lost River Region. The Lost River drainage basin in Orange County, Indiana, exhibits in a typical manner nearly all of the features of a karst region. *Sinkholes* are very abundant. A conservative estimate of the number present in the Lost River basin is 25,000. *Sinkhole* ponds are plentifully present. *Sinking creeks* or *lost streams* disappear in *swallow-holes* in stream beds or at the termini of *blind valleys*. *Sinks* of streams are common. The sink of Lost River and the sink of Stampers Creek are notable examples. *Underground streams* follow cavernous conduits beneath the surface and come to the surface in valleys along the western margin of the karst area as great artesian springs known as *rises*. Rises, *cavern springs* and other springs associated with solution conduits in limestone areas may be called *karst springs*. *Dry-bed channels* are present. The most notable is the storm-water surface course of Lost River between the sink and the rise of that stream. It is 21 miles in length. *Karst valleys* are numerous along the western margin of the karst area between the rugged ridges capped with the Chester sandstones. Numerous blind valleys descend out of the rugged hills to end in the karst valley areas. *Caverns* occur beneath the karst area. Some of them are dry, while others are either permanently wet or are periodically wet when coursed by inflooding storm waters from the surface. A few *gulfs* are present where underground streams are revealed in a floor-like area hemmed in by steep-sided walls of limestone. *Subterranean cut-offs*, *karst tunnels*, and *karst bridges* are rare or wanting. *Lapiez* features are practically unknown, chiefly because bare surfaces of limestone are small or are absent.

Characteristics of Lost River. Lost River heads near Smedleys Station in western Washington County at an altitude of about 900 feet above sea level. In the first 10 or 12 miles of its course it is a normal dendritic system which appears to be consequent upon a regional westerly slope. While this slope is developed on the St. Louis limestone, there is little evidence of underground drainage. The absence of karst features here is difficult to explain, except on the basis that the region is remote from entrenched main streams. This part of the Lost River system occupies rather broad shallow valleys the slopes of which ascend to broad flat divides between the valleys. Near the Washington-Orange county line, about five miles from head of the stream, Lost River is broadly intrenched about 75 feet below the westerly sloping upland plain. A few small sinkholes are present in the upland and springs of clear water enter Lost River in and near its channel. About five miles west of the Washington-Orange county line Lost River enters the sinkhole plain proper. Here the westerly sloping plain has descended to an altitude of about 700 feet above sea level. After traversing the sinkhole plain for about two miles Lost River sinks in a number of inconspicuous swallow-holes in its channel. The sink of Lost River is about 12 miles due west of the head of the main stream and about two and one-half miles south-southeast of Orleans. Lost River reappears on the Allen farm a short distance south of Orangeville and about seven miles due west of the sink of the stream. Its reappearance is in the form of a large artesian spring in the bottom of Lost River valley. It is known as the "Rise of Lost River."

The valley of Lost River in the vicinity of the disappearance of the stream is but little below the general level of the sinkhole plain. The sink of Lost River is about 620 feet above sea level and its rise seven miles away is about 490 feet above sea level. Above the sink of the stream the course is rather direct. The dry-bed channel between the sink and the rise of the stream is a very tortuous meandering route fully 21 miles in length. Flood waters only occasionally follow the entire dry-bed route. Rains are sufficiently severe perhaps four or five times a year to flood the entire route. The upper and lower parts of the dry-bed, however, are flooded frequently.

In addition to the small swallow-holes which convey the low water flow of the spring-fed Lost River to the underground conduit, there are three large swallow-holes in or near the dry-bed in the upper seven miles of the dry-bed course. In order, these are the Stein, the Turner, and the Tolliver swallow-holes (see inset map, Fig. 3). The capacity of each of these swallow-holes is about one-half of the capacity of the dry-bed channel. The first two swallow-holes are able to take in nearly a full channel of storm water. Heavy rains send water to the Tolliver swallow-hole. When the dry-bed waters reach this swallow-hole, it soon becomes taxed to capacity. This is because it has a large amount of water entering it from an underground channel and filling it to near capacity before the dry-bed waters reach it. The flood waters course through the entire dry-bed channel for only a few hours following heavy rainfall. It is then left dry except for stagnant pools here and there along the course. In addition to the large swallow-holes there are numerous small ones along the dry-bed course. Fig. 1 is a view of some of the storm waters disappearing in a small swallow-hole in a stream bed a short distance below the Johnson bridge across the dry-bed about one-half of a mile below the sink of Lost River. Vortices like the one shown in the view are unusual.

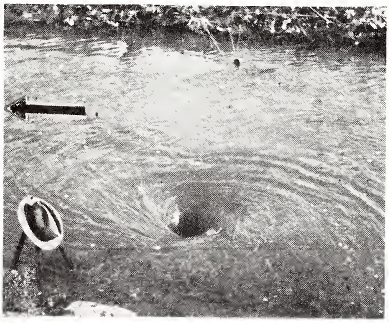

Fig. 1 View showing vortex in Lost River 100 yards below the Johnson bridge southeast of Orleans. This view was taken December 1, 1931. The arrow shows the direction of the stream flow. The vortex is over a swallow-hole in the dry-bed channel about one-half of a mile below the sink of Lost River. Rains caused the stream waters to pass beyond the sink and occupy the upper section of the dry-bed. Vortices like the one shown in the view are very exceptional.

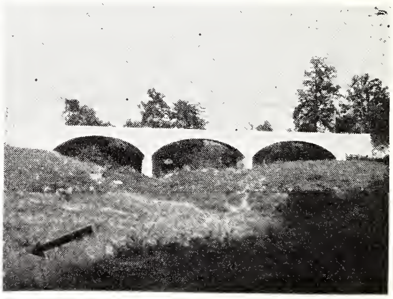

Fig. 2. View showing the dry-bed channel of Lost River at the bridge on State Highway No. 37, three and one-half miles south of Orleans. The dry-bed here is between the Stein and Turner swallow-holes, about two and one-half miles below the sink of Lost River. The arrow points downstream.

The area of the drainage basin above the sink of Lost River is approximately 53 square miles. The middle section of the Lost River basin, or the area between the sink and the rise, consists of about 103 square miles. The section below the rise with relatively little Karst embraces about 160 square miles. Thus about one-half of the system is associated with underground drainage. The middle section is a completely disintegrated or dismembered former surface system. No tributaries reach to the dry-bed which was once the surface trunk stream of the system. The distal ends of the former surface tributaries lose their waters in swallow-holes long before they reach the dry-bed of Lost River. Some of the storm waters during exceptional rains, however, pass over dry beds to the dry-bed trunk stream, or more frequently some of the storm waters rise from their underground conduits and enter the lower part of the dry-bed some distance above the rise of Lost River. On the Mathers place in the southwest corner of Sec. 34, T. 3 N., R. 1 W., about half way between Orleans and Orangeville, a large amount of muddy water rises from a pit and flows into the dry-bed of Lost River. It soon ceases to flow after the storm waters have been drawn off. It is an example of the wet weather rises of underground streams.

It is the middle section of the Lost River basin which is typically karst. At least 60 square miles of this section is an ideal sinkhole plain practically without surface streams. Sinkholes are very abundant. At least 20,000 sinkholes are present in this section of the system. State Road No. 37, "The Dixie Highway," passes through this section between Mitchell and Paoli. The highway bridge across the dry-bed (Fig. 2) is between the Stein and the Turner swallow-holes about three and one-half miles south of Orleans. In one square mile southwest of Orleans an actual count revealed the presence of 1,022 individual sinkholes. The region is literally perforated with holes and is a veritable regional sieve. It represents the perfection of subterranean drainage and of karst topography. Sinkholes more than any other feature characterize karst topography. They exist by the hundreds to one of any other feature of karst.

The western margin of the karst area is the more varied part of the karst terrain. Accessible caverns are relatively scarce in the sinkhole plain. They are more abundant and more readily accessible along the western margin where the rugged ridges composed of the clastic Chester beds rise above the sinkhole plain. Farther south, it is in this marginal area that Marengo, Wyandotte, Mammoth, and other noted caverns occur. Here also are found the karst valley areas, the blind valleys, the rises of subterranean streams, and the gulfs. It is in the western margin of the karst region with its sandstone capped hills and ridges that the older and more accessible parts of underground Lost River occur. Here also occurs the Wesley Chapel Gulf where Lost River rises to the surface in a deep pit in the alluviated floor of the gulf. Underground Lost River is readily accessible from the gulf, and it is here that the characteristics of the underground system are best revealed.

Definition of Gulf as a Karst Feature. The term *gulf* as applied to a feature of karst is the name of a steep-walled or abrupt circumscribed depression which characteristically possesses a flat alluviated floor in which an underground stream rises and sinks. The underground stream may be perennially present and greatly swelled following heavy rains, or it may be exhibited on the floor of the gulf following heavy rains only. The feature is always associated with an underground stream, and its development has been dependent upon collapse of the superincumbent rock over the underground stream and the solution and removal of the fallen rock. Apparently gulfs have their beginnings in collapse sinkholes over an underground stream, and in their earlier stages they are not to be distinguished from such a collapse sinkhole. When such a collapse feature has its steep-walled perimeter enlarged to such an extent that it possesses a distinct alluviated floor in which an underground stream rises and sinks, it then may be called a gulf. The alluviated floor is usually marked by stream-formed channels which pass from the rise to the swallow-hole or series of swallow-holes where the water is returned to the underground channel system. Gulfs characteristically contain a rise and sink of the stream revealed in them. The term does not appear to have been applied to the unroofed section of an underground stream which flows out of an open cavern and across an open space and thence into an open cavern on the other side. No name appears to have been given to this latter feature, though it is a relatively common karst feature. I would suggest *karst fenster*, or *karst window*.

Gulfs of the Lost River Region. Gulf as the name of a karst feature has been used in the Lost River region for more than 100 years. Its employment in the literature has been incidental. Richard Owen (1862, 143-144) refers to the Tolliver swallow-hole and the Wesley Chapel gulf as the "gulfs" of Lost River. He presents a woodcut engraving of the steep face of the Tolliver swallow-hole or gulf. Elrod (1876, 225), states that Lost River "comes to the surface at Wesley Chapel gulf, in section 9, township 2 north, range 1 west, where the superincumbent rocks have fallen in and forced the stream to the surface." He mentions the Wesley Chapel gulf in a subsequent paper bearing on the features of the Lost River region (1899, 263). Beede (1911, 87, 105) refers to the Orangeville rise as a "gulf," but he also briefly describes a well developed gulf about one-fourth of a mile north of the Orangeville rise, referring to it as a "gulf" of Lost River. His description is in the caption to a rather good photographic view taken of a part of the floor and the north wall of this gulf. Malott (1922, 208), in a general description of the features of Lost River, and again in a paper describing cavern stages (1929, 202), describes briefly the Wesley Chapel gulf of Lost River and states that it is the most spectacular feature of the Lost River drainage basin. Davis (1930, 538-539), in his excellent treatise on the origin of limestone caverns, gives a brief description of the gulf.

Four gulfs are present in the Lost River region. The largest is the Wesley Chapel gulf. A map and a description of it constitute a part of this paper. A well developed gulf, which may be called the Orangeville gulf, is located on the Ragsdale farm, about one-fourth of a mile north of the village of Orangeville. The flood waters of an underground stream rise from a pit under the steep north wall of this gulf and sink in swallow-holes at the south end of the gulf. The crest of the north wall is fully 65 feet above the pit in which the storm waters rise. Occasionally storm waters overflow the south end of the gulf. At such times the maximum depth of the water in the gulf is about 35 feet. The underground stream whose storm waters rise in this gulf is the same one that rises at Orangeville. This subterranean stream rise is believed by many to be the rise of Lost River. It is very likely the rise of a subterranean stream which comes from the north and which gets its waters from the sinking streams and karst valleys north and northeast of Orangeville. Certain evidence indicates that the waters of Beaver Creek which enter the cavernous swallow-hole about one-half of a mile west of Georgia come to the surface at the Orangeville rise, fully six miles south-southeast of where they sink. A third gulf in the Lost River region is on the farm of Martin Tolliver, near the southwest corner of Sec. 11, T. 2 N., R. 1 W., about three and one-half miles east-southeast of Orangeville. Lost River uses this gulf as a swallow-hole in times of rather heavy rainfall. It is not a fully developed gulf. Following heavy rains an underground stream enters the gulf from the south side and immediately enters a debris-covered opening. Underground Lost River is accessible from this gulf or swallow-hole. The fourth gulf known in the region is on the farm of Roy Daugherty, a short distance south of U. S. Highway No. 150 and about three miles southeast of Paoli. A large spring, known to be the rise of Stampers Creek, enters Lick Creek nearby. The gulf is known as Crow Hollow. Only storm waters of the underground stream rise in this gulf. Its eastern wall rises nearly 100 feet above the floor across which the storm waters pass. Underground Stampers Creek may be reached in a small cavern a short distance south of the gulf. Stampers Creek sinks four miles northeast of its rise. Crow Hollow gulf is in the Lick Creek drainage basin, though the underground stream responsible for it comes from the Lost River basin from which it has been diverted.

The Wesley Chapel Gulf. The Wesley Chapel gulf of Lost River is located on the farm of James Elrod, a short distance east of the center of Sec. 9, T2N, R1W, about four and one-half miles southwest of Orleans (see Fig. 3). It receives its name from the Wesley Chapel Church at the crossroads a little over one-fourth of a mile north of the gulf. The gulf is on a direct line between the sink and the rise of Lost River, five miles due west of the former and two miles due east of the latter. It is also but little off a direct line between the large swallow-holes along the dry-bed and the rise of the river. The dry-bed channel passes about three-fourths of a mile northwest of the gulf. The gulf is in the western margin of the karst belt where numerous karst valleys occur between the rugged ridges capped with the Chester sandstones. It is, therefore, a little west of the sinkhole plain proper. As a surface feature it is entirely in the St. Genevieve limestone. The Lost River chert, near the base of the St. Genevieve, is exposed in places at or just above the level of the alluviated floor of the gulf.

The Wesley Chapel gulf is an abrupt steep-sided depression in a gently undulating soil-covered area of cultivated farm and pasture land.

It is rimmed by trees which partly obscure it during the foliage season. The topographic details are depicted in Fig. 3. The gulf is about three times as long as it is wide, measuring 1,075 feet in length and averaging about 350 feet in width. Its long axis extends north 35 degrees west, or nearly northwest by southeast. Its perimeter measures about 2,700 feet, and encloses an area of 8.3 acres. The floor area is about 6.1 acres. The gulf depression has rounded ends and is slightly constricted in the middle. A broad shallow valley on the north end of the gulf has been interrupted by the development of the gulf. The upper part of this valley, entering from the east, has a hanging relationship to the gulf. Storm waters descending into the gulf from the hanging valley have cut a V-shaped notch in the perimeter of the gulf. The counterpart of this notch is present on the west side of the gulf near the south end, where a mass of broken-down blocks of limestone protrude about 100 feet directly into the gulf. Other than these two features the outline of the gulf depression is quite regular.

Both the north and south ends and the western side of the gulf are nearly or quite perpendicular through a part or all of their ascent above the gulf floor. They are wall-like or form a nearly continuous cliff. The eastern side, except at the south end, is an abrupt acclivity, but is not in the form of a cliff. A roadway descends obliquely along the east side to a cornfield of about two or three acres planted annually on the alluviated floor of the gulf. The height of the walls varies from about 25 feet on the northwest to about 95 feet on the southeast.

The altitudes about the perimeter of the gulf varies from 595 feet above sea level along the north part of the west side, to 640 feet on the southeast where the gulf is developed out of higher land. The lower part on the north is associated with a former surface valley leading west. The development of the gulf disrupted the surface valley and now the storm waters which descended through the upper part of the disrupted valley plunge into the gulf and become subterranean. Attention has already been directed to this hanging valley on the east. The altitude of the alluviated gulf floor is between 570 and 575 feet above sea level.

The floor of the gulf is marked by the deep mud-lined pit of the rise of Lost River at the south end of the gulf and by the overflow channels which lead away from the deep pit. Numerous rather inconspicuous swallow-holes are present in the overflow channels. Two views of the pit taken from opposite sides are shown in Figs. 4 and 5. During low-water periods the waters in the pit are 25 or 30 feet below the level of the gulf floor, and carefully made soundings indicate a maximum depth of 20 feet. The pit is, therefore, 45 or 50 feet deep. The local tradition is that it is bottomless. It lies in the shadow of the abrupt south wall of the gulf which ascends fully 95 feet above the low-water surface in the pit. During the low-water periods the water is clear and frequently of a deep blue color. The water surface is nearly circular and is about 75 feet in diameter. The surface is perfectly calm. The water quietly leaves the pit at the south side and immediately disappears without demonstration in the mud-covered talus rock accumulated at the foot of the towering south wall of the gulf.

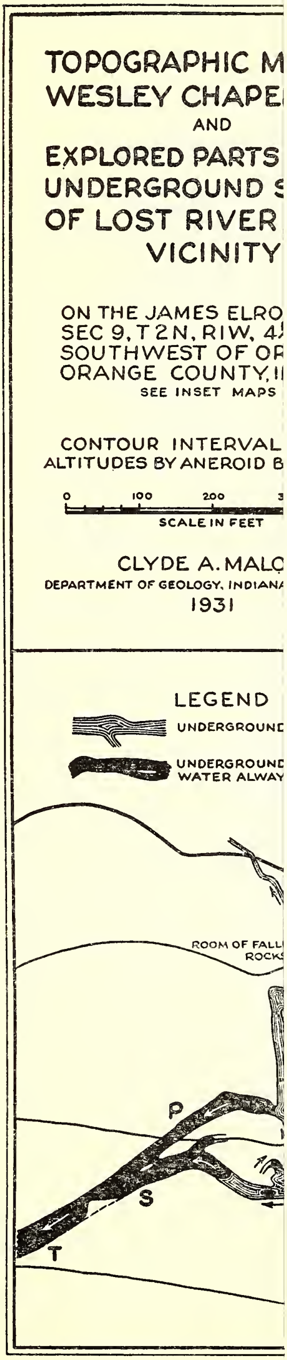

Fig. 3. Topographic m

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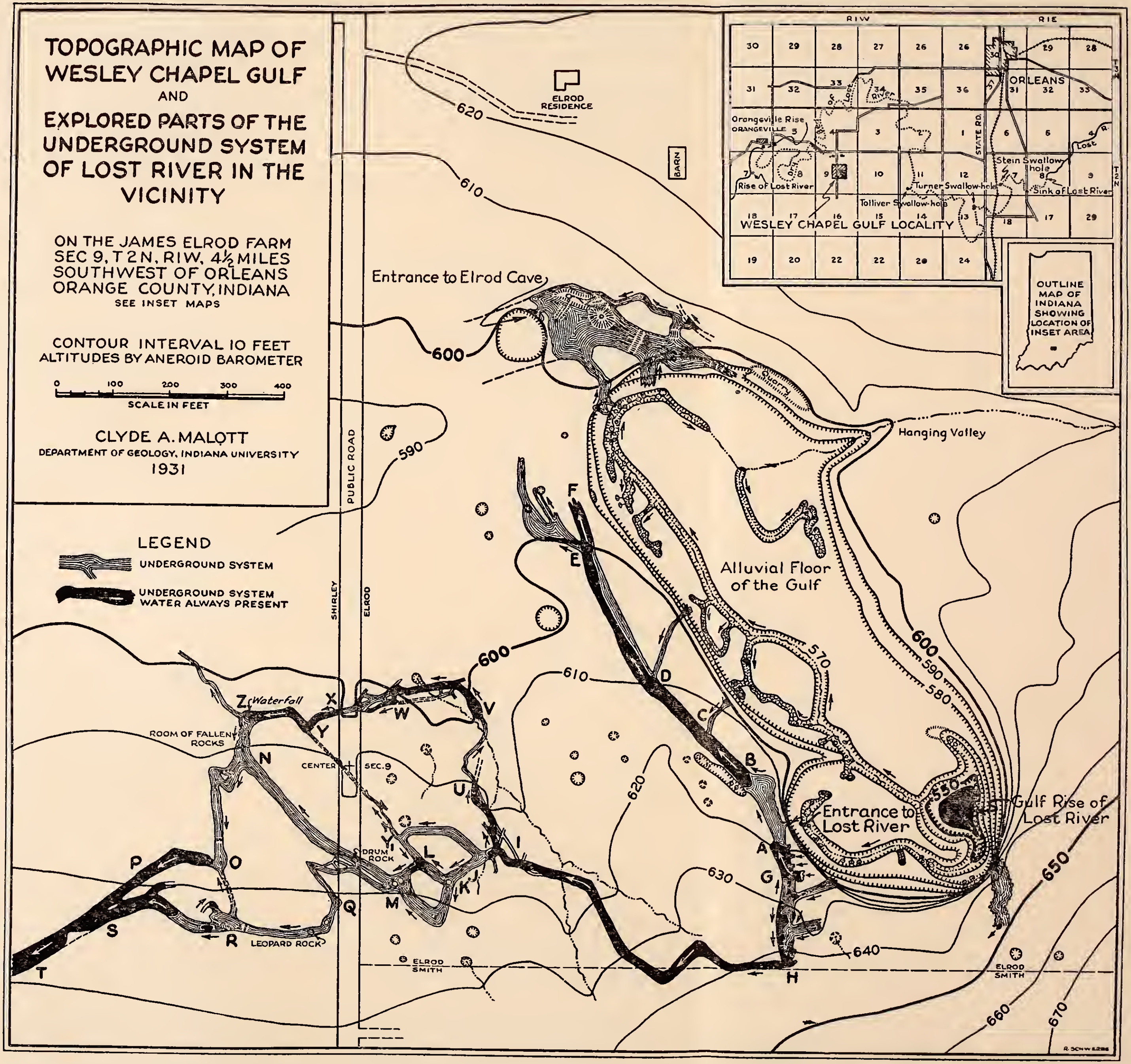

Fig. 3. Topographic map of the Wesley Chapel gulf and vicinity, with the map of the explored parts of underground Lost River near the gulf.

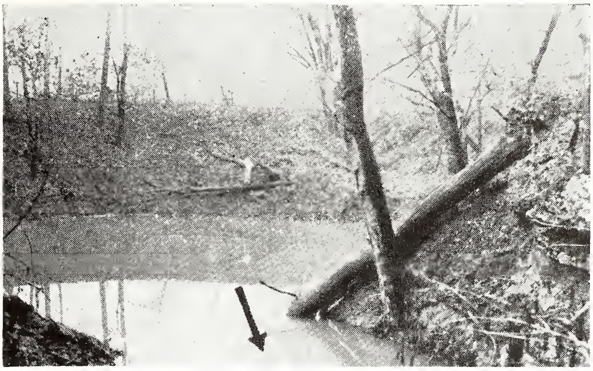

Fig. 4. View of the gulf rise of Lost River at the south end of the Wesley Chapel gulf, looking north. The waters of Lost River rise from the bottom of the pit and flow southeast out of the pit (arrow shows direction of flow). The water in the pit during low-water periods is 20 feet deep. The full depth of the pit is 45 or 50 feet. The eastern wall of the gulf shows indistinctly in the background.

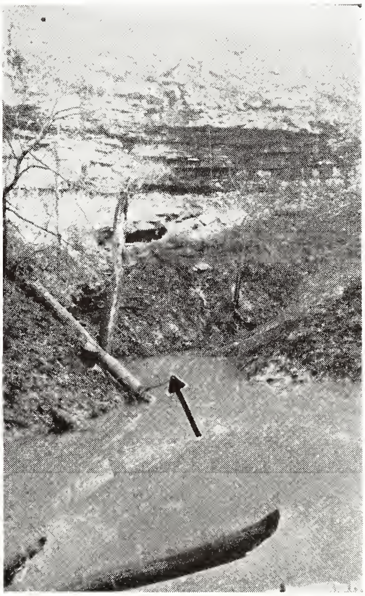

Fig. 5. View across the gulf rise of Lost River in the Wesley Chapel gulf, looking south. The waters flow out of the pit and disappear in mud-covered talus rock just beyond the arrow. The south wall here towers 95 feet above the water in the pit. The cavern opening in the wall receives waters during high flood periods. It is 25 or 30 feet above the low-water level in the pit. All of the rock exposed in the view belongs to the St. Genevieve limestone.

During high-water periods the rising waters are very turbid and yellow with clay and silt. The pit fills to overflowing and discharges into the two flood-water channels (shown in Fig. 3) without any great show of turbulence. The storm waters on leaving the pit through the high-water channels fill to capacity each swallow-hole in succession until all are in use that are reached by the high waters. The channel about the southern end is the first one used, and, upon the subsidence of the high waters, it continues in use for a short time after the waters have ceased to enter the longer northern channel. (See Fig. 6.)

The northern overflow channel, leading west from the deep mud-lined pit, is relatively free of swallow-holes except at the north end. It has, however, overflow connections with numerous swallow-holes along the west side of the gulf floor next to the western wall. This channel extends to the extreme northern end of the gulf and then curves back into the alluviated floor of the gulf, and, after being joined by the channel from the hanging valley coming in on the east, it turns toward the east wall of the gulf where it ends in a group of shallow swallow-holes. On the day that the floor of the gulf was mapped in preparation of Fig. 3, September 18, 1931, a careful count of the swallow-holes in the floor of the gulf revealed a total of 100. This number includes the small ones of little importance and probably of temporary position, as well as the more important larger ones.

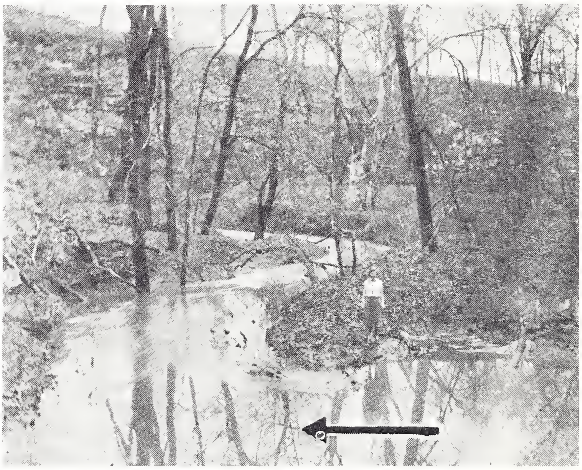

Fig. 6. View of flood waters flowing from the gulf rise of Lost River in the south end of Wesley Chapel gulf. Arrow shows direction of flow from the pit. The waters leaving the pit through the overflow channel disappear in a number of swallow-holes on the west side of the gulf. View taken November 19, 1931.

During high-water periods most of the waters disappear immediately south of the pit. These waters find their way through the chinks between talus blocks of limestone which underlie the overhanging south wall here. Apparently an underground channel passes westward below the level of the floor of the gulf and a short distance back from the foot of the south wall. During exceptionally high waters, entrance is gained directly through a cavernous opening in the south wall 25 or 30 feet above the low-water level in the pit. This cavern (the opening of which may be seen in the view, Fig. 5) can be followed back and downward for about 100 feet over and through broken limestone. The waters which pass through the limestone blocks very likely reach the underground channels west of the gulf (see Fig. 3). Most of the waters which course through the southern overflow channel disappear near the end of this channel under the shadows of the western wall of the gulf. The waters pass to the underground channel system through limestone talus obscured on the outside by the accumulated alluvial material on the gulf floor. The presence of the accumulated limestone talus at the foot of the western wall prevents a direct entrance of the waters to the underground system at this place. It is at this place, between the backslanting wall of the gulf and the accumulated talus underfoot, that a manhole-like opening leads steeply downward to the underground channel of Lost River (see Fig. 7).

A third place where large amounts of flood water disappear is near the north end of the gulf. Waters pour in very noisily at two or three holes along the western wall. Very likely these waters reach the underground channel beyond the broken-down terminus reached in the exploration of the channel leading northwest parallel with the western gulf wall (see Fig. 3). Part of the waters which disappear near the north end of the gulf through the numerous swallow-holes lead into the Elrod cavern which is free of stream waters except during floodings of the gulf.

Very heavy rains bring about a complete inundation of the gulf floor. The flood waters may rise as much as three to five feet over the alluvial floor. Such floodings may occur as often as five or six times a year. Usually they take place in the late winter or in the spring. Occasionally, however, the gulf floor may be inundated during the growing season. Mr. James Elrod relates an interesting occurrence in the flooding of the gulf floor about 15 years ago. He had plowed and prepared the ground for planting, but on account of approaching darkness he did not get the planting done. It was just as well that he did not, for on his return the next morning he found the floor of the gulf under several feet of water. It had not rained in the locality of the gulf, but a heavy rain had taken place in the headwater portion of Lost River the day before. During the night the waters rose in the gulf and completely flooded it. The flooding of the gulf floor takes place because the waters rise into it from the pit faster than it gets away through the numerous swallow-holes. It is believed that the floodings take place more on account of the limited capacity of the underground channel system west of the gulf than on account of the limited capacity of the numerous swallow-holes through which the waters escape from the gulf.

Underground Lost River. Underground Lost River begins at the sink of the surface stream in its channel a short distance west of the center of section 8, T2N, R1E, on the Donald McCart farm, about five miles due east of the Wesley Chapel gulf. Little is known about the underground system in the upper few miles of its underground course, as the openings leading into it are too small to permit entrance and exploration. At the sink the waters descend quietly by entering small openings along the right bank of the stream and in the floor of the channel. None of these holes is conspicuous. The surface channel here is about 620 feet above sea level. It is not likely that the underground channel is very deep below the surface. It does not appear that it could be more than 20 or 30 feet, and it is very likely less. No holes are known at the Stein and Turner swallow-holes which are large enough to enter. It is possible that entrance could be gained at one or the other of these localities were it not for the timber rafts which have accumulated about the more important swallow-holes.

A small collapse sinkhole on the Chas. T. Brown farm, in the NE ¼ Sec. 14, T2N, R1W, leads directly into a cavern system believed to be a part of the underground Lost River system. The writer and Robert Shrock explored and carefully mapped about 3,200 feet of this system in 1929. Three different levels are represented. Only storm waters pass through the explored system. The lowest level has an altitude of about 555 feet above sea level. It is about 40 feet below the dry-bed channel. High-water level in the cavern system is 45 feet above the lowest floor, and is about at the same level as the storm waters in the dry-bed following heavy rains. The system explored on the Brown farm lies between the Turner and the Tolliver swallow-holes, and a little south of the dry-bed channel. The storm waters which course through the system are believed to enter at the Turner swallow-hole complex a little less than one mile east of the entrance into the system on the Brown farm.

A short stretch of about 300 feet of underground Lost River at the Tolliver swallow-hole was explored and mapped by the writer and Robert Bates during the summer of 1931. The passage from the swallow-hole leads north 565 feet and connects with the river. This passage itself is a part of the underground system. It carries storm waters only. The river has an altitude of about 545 feet, and is but little above the low-water level in the pit at Wesley Chapel gulf, a mile and one-half to the northwest.

A short distance south of the center of section 8, a little more than one mile west of the Wesley Chapel gulf, a short channel leads from the dry-bed to a cavernous opening in which water stands at a level about 10 feet below the dry-bed and at an altitude of about 515 feet. This opening receives considerable quantities of storm water from the dry-bed when waters first course down the dry-bed following rains. If the rains are heavy, the water flow is reversed and waters pour out of the opening vigorously. Thus the opening is a swallow-hole for brief periods and a rise at other periods. It is thought that the opening leads directly into the underground Lost River system, as it is located directly between the Wesley Chapel gulf and the rise of Lost River on the Allen farm about three-fourths of a mile south of Orangeville.

It appears that underground Lost River lies 40 to 80 feet beneath the general sinkhole plain. Where it passes beneath sandstone capped ridges in the western part of its underground course, it is as much as 150 or 200 feet beneath the surface. It is not a direct single conduit, but is a rather complex compound system both laterally and vertically.

The system is partly developed in a northwest-southeast joint system and partly in a southwest-northeast system. Some of it is above the water table and some of it is below. The system is developed in the top of the St. Louis limestone near the contact with the St. Genevieve limestone above. The parts of the system accessible at the Wesley Chapel gulf locality, described below, are illustrative of the complexity of the system.

Underground Lost River at Wesley Chapel Gulf. Underground Lost River is readily accessible at the Wesley Chapel gulf through a small opening which leads steeply downward between the western wall of the gulf and the talus rock underneath (see Fig. 7). The location of the opening here is dependent upon the proximity of the underground channel to the western wall of the gulf (see Fig. 3). The underground channel has long been known here, though very little is known about it. Elrod (1876, 225), refers to an exploration of the underground system made some years previous to 1875, and Rhodes (1905, 7-11), gives an account of an exploration which took place about 1875. Apparently no map of the underground system has been attempted previous to the work of the present writer. A brief characterization of the underground system at Wesley Chapel gulf was published by the writer a few years ago (Malott, 1929, 202-203). Since then a careful map has been prepared. It constitutes a part of Fig. 3 of this paper. Davis (1930, 541) presented a part of the mapped system from the unpublished maps furnished him

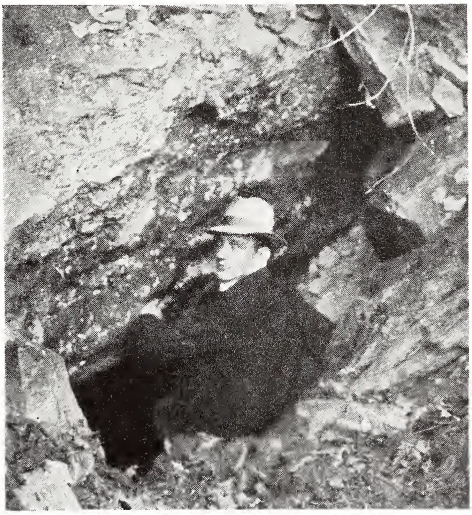

Fig. 7. View of the manhole-like opening into underground Lost River in the western wall of the Wesley Chapel gulf. The opening is 35 feet above the underground stream. The rock ledge at the level of the opening is the Lost River chert near the base of the St. Genevieve limestone. The underground channel below is in the St. Louis limestone.

by the writer before the mapping of the system there was fully completed.[1]

In presenting the following description of the underground system of Lost River in the Wesley Chapel gulf locality, free use is made of the map of the system shown in Fig. 3. The letters, A, B, C, etc., refer to special features and positions along and in the mapped system. They serve as location points in the description. The positions to which they refer may be readily ascertained by consulting Fig. 3. Only one differentiation is attempted in the map of the underground system. Places in the system where water is continuously present are indicated in solid black. Other parts of the traversed system are shown by water-line shading. It should be borne in mind that practically the entire system is completely filled with water during periods of surface floods.

The small manhole-like opening, Fig. 7, leads directly into a north-south stretch of underground Lost River, the floor of which is about 30 feet below the alluviated floor of the gulf. From A to B, a distance of 115 feet, the eastern side of the underground channel is composed of a talus accumulation which separates the gulf outside from the underground route on the inside. The western (left) side and the ceiling are really the undercut western side of the gulf wall below the level of the alluviated floor of the gulf. At A, 35 feet down and 35 feet forward from the opening into the underground system, the swiftly moving waters of underground Lost River come from a southerly direction and disappear in the talus rock along the western wall of the channel. To the right (slightly west of north), a rocky passage about 10 feet above low-water level extends towards B. This passage is occupied by muddy waters during periods when the gulf is flooded. At B, the waters of the underground river flow out of the talus rock and pass in a northwesterly direction through a cavernous passage in solid limestone. Back from where the waters issue, the talus rock rises for a distance of about 40 feet before coming in contact with the roof-rock above. During high-water periods much water enters through the talus rock and along the northern end of the passage A-B. The freely flowing water which disappears at A passes along the western or left wall and beneath the talus rock. Apparently the waters are dissolving away the foot of the western wall as well as the talus rock through which they pass. The talus crowds the waters to the western wall, and the dissolution of the rock there continues to undermine this wall of the gulf. Further collapse of the overhanging gulf wall will add to the size of the gulf outside.

Beginning at B, the underground channel leads in a northwest direction with but little deviation to F, a distance of 600 feet. This passage is 5 to 15 feet in height and 15 to 35 feet in width. The floor is covered with water over much of the route from a few inches to about three feet in depth, except at two places, C and D, where it is five feet or more in depth. The passage is almost parallel with the west wall of the gulf and is 50 to 100 feet from it. The water-covered floor has an altitude of about 540 feet above sea level. The passage is, therefore, 60 to 70 feet beneath the surface. At C, 110 feet from the beginning of the water course at B, a storm-water tributary channel enters from the right. This passage is about two feet above the water in the river channel, and the storm waters which enter here have formed a plunge basin about five feet deep. The channel is rather uniformly five feet high and six feet wide. In the clean-washed rock bottom are numerous potholes and solution ripples or facets. This passage leads back 75 feet in a northeasterly direction. It ends in a mass of fallen rock beneath the western edge of the gulf. It is evident that the passage conveys storm waters from the gulf during periods of high water. Another passage of similar character enters the main passage at D, about 250 feet from the beginning of the water channel at B. This passage is about five feet in diameter and leads back 140 feet in a northeasterly direction, where it also terminates in a mass of fallen rock under the western edge of the gulf. Waters appear to enter the passage near the bottom of the fallen rock. This passage without doubt is a route of swiftly moving waters during high-water periods in the gulf. The passage is three or four feet higher than the river channel into which it enters. The floor of this tube-like passage is marked by numerous potholes from a few inches across to large ones three feet in diameter. Many of them are perfectly developed, while others form a coalescing series. Their depths are from a mere trace to about two feet. The most perfect ones are four to eight inches in diameter and four to ten inches in depth.

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[1] The map of the underground system, as shown in Fig. 3 of this paper, is a result of string and compass traverses made by the writer and Robert Shrock in 1929, and several additional traverses made during 1931 by the writer and John Huddle, Robert Bates, and Richard Schweers. Also the writer is indebted to his two sons Roland and Floyd Malott, who have accompanied and greatly aided him on many visits into the underground system.

Beyond D the water is shallow and flows in noisy ripples over the rock floor of the channel. It follows the left side of the channel and has undercut the left wall. A ledge of rock two feet thick has fallen from the roof and lies in blocks without much derangement. The channel here is fully 35 feet wide. Its height is only a few inches above the water on the left side, but it is six feet or more on the right. About 175 feet beyond D, a rock fall from the roof is covered with mud from one to three feet in depth, and on the mud are many peculiar mud stalagmites. Sticky mud also coats the walls and the roof of the cavern. Stalactites hanging from the ceiling are composed partly of mud and are rather insecurely attached. Most of them are quite firm with mineral matter, though partly composed of mud. Apparently the mud has come from the storm waters which at times completely fill the cavern system. During low-water periods the mud coatings are succeeded by the precipitation of normal dripstone calcite. The mud stalagmites have a unique origin, and they form the subject of a special paper.[2]

The water is shallow over the broad floor near E and beyond to F, at the end of the water passage. The amount of the water is considerably diminished, indicating that some of the stream water escapes on the left side before reaching E. At the end of the passage the water enters dissolved-out crevices in the beds of limestone. A large crevice on the left was followed for a distance of about 25 feet. It appears that the limestone rock has settled down in the passage without much breaking, thus terminating the passage. At E, an opening leads to the left of the main passage to a level about 10 feet above the floor of the main passage. In this higher level about 65 feet from E, a broken-down rocky passage leads off to the right for a distance of about 85 feet. Near the end, water may be distinctly heard running under the fallen rock below. To the left, about 65 feet from the beginning of this passage at E, the cavern leads up some 10 or 15 feet into a high-level expansive cavern with a width of 30 or 40 feet. It then leads off northward for about 130 feet where it ends in blocks of fallen rock. Water also may be heard quite distinctly trickling through the fallen blocks below. The floor of the expanded cavern room is composed of mud. The highest part of the ceiling here is not coated over with mud. Apparently the muddy storm waters do not reach much higher than about 35 feet above low-water level in the underground river.

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[2] Malott, C. A., and Shrock, R. R., Mud Stalagmites.

The main passage from A to F is 715 feet in length. The two floodwater passages leading from under the gulf are 75 and 140 feet respectively. The cavern complex at a higher level on the left at E shows a total traverse of 300 feet. The entire system on the left of the opening at A has a traversed length of 1,230 feet.

A much larger section of the underground system is available to the left of the opening at A. The water encountered at A, just below the entrance to the system, is one to three feet deep during low-water periods. The waters seen here enter the channel from the left wall in a stretch of about 65 feet in length. Most of it comes out at G, where an opening reaches back about 20 feet. The water comes out through fallen blocks of rock and from low channels dissolved out of the cherty limestone. The main channel from A to G is five to eight feet high and 15 to 20 feet wide. From G to H, the main passage continues nearly south for a distance of 150 feet. Little water is present in this stretch during low-water periods. The passage here is 20 to 30 feet in width and eight to 15 feet in height. The first 50 feet of the floor is covered with mud from a few inches to one foot or more in depth. A small rivulet of water flows north through a mud groove, entering the main flow of water at G. The remaining part of this stretch of the channel is covered with blocks of clean-washed rock. About midway is a pool of water about 30 inches deep. Along the right wall, water flows slowly southward, opposite in direction to that at the north end of this channel stretch. At H, considerable water enters from the left through low cavernous openings in the cherty limestone. Here begins a stretch of river water which continues forward without interruption for 655 feet. Between G and H, however, two cavernous openings, four to seven feet high and 10 to 20 feet wide, enter from the left. The first of these is 35 feet beyond G. It leads back in an easterly direction for 95 feet, where it terminates in a mass of fallen rock beneath the western edge of the gulf. The second passage is about 100 feet beyond G. It is very similar to the first, except that it leads back only about 50 feet. It is apparent that the storm waters entering the main channel from these two tributary channels during high-water periods turn southward rather than northward. The divide of the high waters appears to be represented in the muddy stretch of the passage just beyond G. The waters which fill the passage here are between stretches which flow in opposite directions, and the clay silts which settle out are not carried away.

At H, 250 feet south of the entrance into the underground system, a stretch of water begins which extends mainly west and northwest for 655 feet. In this water course the channel is relatively simple. It is seven to 15 feet in height and 12 to 30 feet in width. It is characteristically eight or nine feet high and 15 feet wide. It is clean-washed and few or no rock masses litter the floor. The water ranges from a few inches in depth over noisy shallow places to about 30 inches in depth in the broad quiet pools, except at the sharp-angled turn 165 feet beyond the beginning of the water stretch, where a depth of seven or eight feet occurs. The deep water may be avoided here by staying close to the left wall on the inside of the turn. Figs. 8 and 9 are views of the cherty St. Louis limestone walls just above the water level at or near the beginning of the water stretch at H. Solution of the limestone leaves the chert masses and nodules in relief over the surfaces. Corrosive erosion by the flowing waters has scalloped out hollows with sharp ridges and horns separating them. These scalloped out places are conspicuous in the limestone walls immediately above low-water level (see Fig. 9). Fig. 10 is a view showing the water during a low-level period flowing over a narrow shallow stretch about 350 feet beyond H.

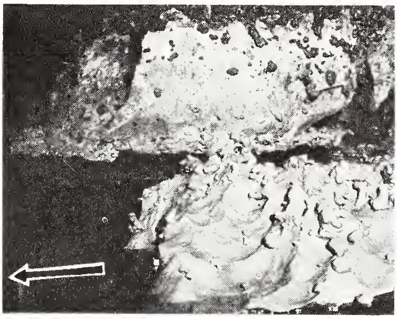

Fig. 8. View of the cherty St. Louis limestone in underground Lost River about 250 feet south of the opening in the western wall of the Wesley Chapel gulf. Spherical and elongated nodules and cellu'ar masses of flint or chert are etched out in relief on the walls of the underground channel.

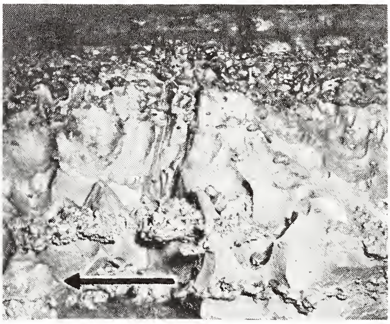

Fig. 9. View of the north wall of the underground channel of Lost River just above low-water level about 40 feet downstream from the view shown in Fig. 8. Scalloped or hollowed out places in the limestone body in which ragged masses of cellular chert occur are rather common in the underground channel. The condition is a result of corrosive erosion by the swiftly flowing waters of the underground stream.

At I, the water leaves the main channel and enters a broken-down complex which extends in a northwest direction in harmony with one of the well developed joint systems. The main channel turns abruptly to the southwest in harmony with a second main joint system. The floor of the main channel is three or four feet higher than the low-water level at I. The floor of the main channel beyond I is very rough with solution pits and potholes. We have called the main channel from I to N "Pothole Avenue." The course of the main channel is indicated in Fig. 3 by the letters I, J, K, L, M, N, O, P, and T. It is seven to 12 feet in height and 15 to 20 feet in width over much of the way.

Beginning at I, "Pothole Avenue" extends southwest to K, a distance of 115 feet. At K it makes an abrupt turn to the northwest, a direction it holds only for about 50 feet. Here, at L, it extends southwest again for 65 feet to M, where it turns abruptly again to the northwest. It continues northwest to N, a distance of 350 feet. The changes in direction are dependent upon the development of the channel along the two sets of prominent joint systems which intersect nearly at right angles. Just beyond I, a small tube-like channel two or three feet in diameter leads off on the left. It is some five feet above the floor of the main channel. At J, about 40 feet beyond I, a wide passage leads off to the right. After making three angular turns to the left and traversing a distance of 210 feet, it returns to the main channel at L. At Y_1, in this side circuit, a small channel leads off to the northwest. It was traversed with considerable difficulty for distance of about 100 feet. It is slightly uneven in size and has connections with tube-like channels at one or two places which parallel it at slightly higher levels. It is of special interest because it connects directly along a northwest extending joint with the water channel X-Y-Z, and the noise made by the falling water at Z is conveyed through it.

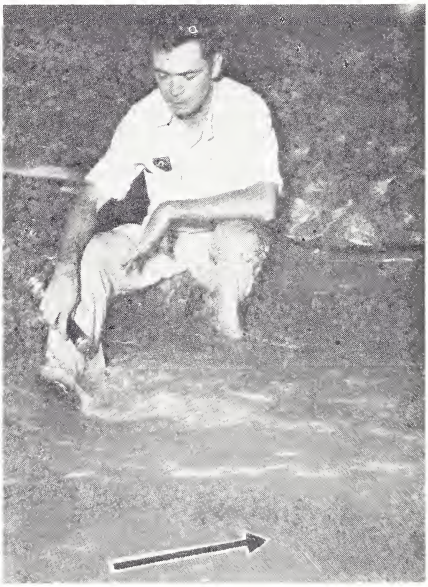

Fig. 10. View showing the swift waters of underground Lost River over a narrow and shallow stretch about 600 feet south and west of the opening in the western wall of the Wesley Chapel gulf.

A ragged rock pillar stands in the broad opening of the beginning of a rock-littered circuit and the abrupt turn of the main channel at K.

The broad circuit leading off to the left at K makes one abrupt turn and returns to the main channel at M, after traversing a distance of 175 feet. A small pool of water a little over one foot in depth occurs at L in the main channel. The floor of the main channel just beyond L is very rough with solution pits and potholes. Fig. 11 is a view taken of the potholes here. At M two angular rock pillars support the broad space of roof-rock where the side circuit returns on the left and where an important branch from the main channel leads away on the same side. Here, also, the main channel turns to the northwest. The floor is rugged with great blocks of loose rock and with holes broken through to a lower level a few feet below. About 75 feet beyond M the floor of the main channel is completely broken down for a few yards. At the far side of the broken-down space a ledge of limestone extends across the empty space beneath. Its upper surface is exceedingly rough with solution pits and potholes, some of which perforate it. When stamped upon it gives forth a hollow drum-like sound. This ledge may be called "Drum Rock." It is located under the public road between the Elrod and Shirley farms about 150 feet south of the center of section 9. The underground channel here is 75 feet below the surface. Several other holes occur in the floor of "Pothole Avenue" beyond "Drum Rock." Towards the end of the 350-foot northwest stretch, great blocks of rock have fallen from the roof and the floor rises about 10 feet at the end of the passage at N. Back from the fallen rock mud has accumulated along the right side of the channel, forming a steep bank against the rock wall. Numerous mud stalagmites have been formed on the mud bank. Many of them exceed a foot in height.

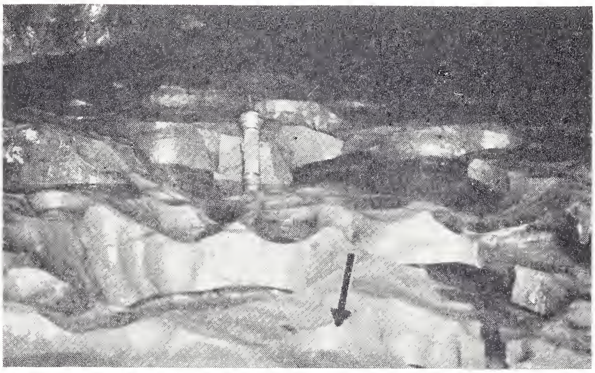

Fig. 11. View of the corrosively eroded floor of underground Lost River in "Pothole Avenue," about 1,110 feet from the opening in the western wall of the Wesley Chapel gulf. The floor is very rough with solution pits and potholes which are difficult to distinguish. "Pothole Avenue" is a few feet above the low-water level of the underground stream.

The long northwesterly stretch, M-N, terminates in a nearly north-south stretch of cavern piled high with fallen blocks of massive limestone. The angular blocks of rock nearly fill the space to the roof in places, while in other places the roof is fully 15 feet overhead. The stretch expands in places to a width of about 40 feet. We have called this rock-filled stretch, extending north 70 feet and south and west for about 100 feet, the "Room of Fallen Rocks." At the north end of the "Room of Fallen Rocks" the turbulent stream X-Y-Z, descends into a lower level, and the noise of the falling waters is exaggerated into a solemn roar in the still cavern air a short distance away. From N the expanded main channel leads southward about 70 feet, and thence west and northwest about 40 feet. A great angular rock pillar stands in support of the roof amidst great blocks of fallen rock near the south end of the room. It is apparent that during times of high water the "Room of Fallen Rocks" has water entering it both from the north and from the east. At the abrupt turn southward out of the room, about 95 feet southwest of N, freshly fractured rock shows conspicuously near the ceiling and on the left wall. Also fragments of the fresly fractured rock were observed on the floor nearby, indicating that some settling of the roof-rock has taken place recently.

The passage southward from the "Room of Fallen Rocks" is practically free of floor fragments. The passage is 10 to 15 feet wide and about 10 feet high. The floor is clean-washed and bears evidence of swiftly flowing flood waters. It bears a little east of south for 120 feet to O, where it reaches a great collapse pit in which the waters pass to a lower level about 15 feet below. The upper level appears to terminate in this pit. The underground channel simply descends to a lower level. At the south end of the pit a small rough-hewn channel comes in from the south nearly at the level of the floor of the pit. It bears marks of water currents entering the pit. To the right, at the south end of the pit, a low opening leads west into a water channel 25 or 30 feet wide and about five feet high. This broad low-roofed passage is half filled with dead or standing water. It extends in a westerly direction for about 80 feet and then turns southwesterly. It was followed to P, about 50 feet beyond the turn to the southwest, where the water becomes deeper and the ceiling descends to within one foot of the water level. An oozy mud covers the rock floor. The altitude of the dead water here is about 525 feet, and the underground channel is about 95 feet beneath the surface. The traverse, ending at P and beginning at the opening in the west wall of the gulf, is 1,870 feet in length along the course of the main channel.

Returning to M of the main channel, it was noted above that an important channel leads off on the left. M is 1,135 feet from the opening in the gulf wall which leads into the underground system, and is marked by two angular rock pillars near the entrance of the channel which leads away from the main channel. This channel joins the main channel at S, a short distance below the end of the traverse of the main channel at P. Its length is about 750 feet. Immediately after leaving the main channel it turns to the right and parallels the main channel for 70 feet. Here it connects with the main channel through a low opening near "Drum Rock." The channel, however, turns to the left in a southwest direction, and thence a little north of west for 75 feet to a very abrupt elbow turn to the southeast. In the stretch between the low connection with the main channel and the elbow turn, three small tube-like channels lead away on the right. These all connect some 20 or 25 feet from where they leave the channel. A small opening from them leads into the main channel just beyond "Drum Rock." The channel, M-Q-R, is 10 to 12 feet wide and five to eight feet high. The floor is very rough with solution pits and potholes. Knife-edge partitions and horn-like projections rise between the separated and coalescing potholes and solution pits. Walking over the rough floor is difficult. At the elbow turn is a small pool of water and some angular blocks of loose rock on the floor. The channel leads southeast 80 feet from the elbow turn to the next turn at Q. Here a small hole is present in the floor leading to a lower level. On the right or the inside of the turn at Q, a short fat drip-stone column has been built by waters seeping from the roof. It fits illy both against the ragged wall and the rough floor. The floor appears to have been partially dissolved from under it. From Q the channel bears to the right finally extending a little north of west at R. About 45 feet beyond Q, a small pillar of rock divides the channel, and about 90 feet beyond Q, a large block of rock nearly obstructs the channel. The flood waters which pass over its upward sloping surface have carved numerous solution ripples or facets which give it a spotted appearance. We called it "Leopard Rock." About 100 feet beyond "Leopard Rock," the channel appears to end in a mud-covered stretch 65 feet long in which are two conical pits 15 feet deep. At the end of the channel, a flowstone mass is built over the rock below an opening one foot high and six feet wide. The opening leads into a small channel practically at the level of the roof of the channel above the mud-lined pits. Water trickles over the flow stone, and a level rim has been built up at the upper edge. This rimstone ponds back a pool of remarkably clear water. The upper level was entered, but not explored. The pits at R are 500 feet from M at the beginning of this channel branch.

Rough cherty limestone shows in the bottom of the pits. Both of the pits have openings along the left wall to a lower level. This lower level was not discovered in the first exploration and mapping of the underground system. It was first entered by the writer and John Huddle in October, 1931. A ledge of limestone a little over one foot thick appears to have been completely dissolved away underneath the pits. A broad low passage leads northward in the direction of the main channel at O, which is less than 100 feet distant. There is little doubt about a connection existing between the pits of the two channels and it is clear that waters pass from R to O through the passage. Most of the waters leaving the pits at R, however, pass through a low broad channel which leads westerly and connects with the main channel at S. This channel is only about three feet high and 10 to 15 feet wide for some 50 feet or more. Farther on it gets wider and higher. The ceiling and side are fantastically rough with protruding masses of cellular and ball-like nodules of chert etched out in relief by the solution of the limestone about them. About 100 feet from R, water is encountered on the floor of the channel. A small low tributary enters on the right about 140 feet beyond R. The dead water deepens to about three feet at the junction of the channel with the main channel at S. Here the water expanse across the channel is fully 40 feet wide. The cherty limestone partition between the two channels is broken through about 25 feet back from the junction at S, and the water expands through the low opening between the two channels. The ceiling here is flat and is two or three feet above the quiet water. From S to T the water deepens to about five feet. A constriction appears in the channel above the water about 75 feet beyond S. The channel, however, maintains its breadth of 30 or 40 feet beneath the surface of the water. At T the ceiling comes within less than one foot of the water, and it is impossible to follow the underground channel farther. The end of the traverse at T is 2,170 feet from the entrance along the main channel and 2,040 feet distant through the branch which leaves the main channel at M. This is the most distant point reached in the explored parts of the underground system in the Wesley Chapel gulf locality.

One of the most interesting places in the mapped system is where the underground stream, H-I, leaves the main channel for a smaller poorly developed route, I-U-V. The influence of the joint systems in the development of the solution channels is quite evident in the network present here. It is apparent that two levels are present in this locality. The upper level consists of tube-like channels two to three feet in diameter. The higher channels are followed only during high-water periods. The lower level system is five to eight feet below the upper. It is a few feet lower than the main channel system beyond I. It appears quite probable that the main channel system has been developed out of the upper system by enlarging it and cutting the floor considerably below the primitive tube-like system that the invading surface waters inherited from the more or less static groundwater development of the system before the water table was lowered to the present levels beneath the surface. At I, the low-water flow of the underground stream has been diverted from the main system through a low system which yet retains some of its primitive characteristics. The water which now courses through it will eventually enlarge it and give to it the same general characteristics of the well developed main system.

At I, the main system is deepened nearly to the level of the youthful system into which it is diverted. In the ceiling above, an opening extends upward perhaps 10 feet into the roof-rock. Beautiful clusters of stalactites have been formed by water seeping through the rock here. The water leaves the main channel through blocks of rock where the upper and lower systems have merged through collapse of the rock separating them. The water passes through the fallen rock from I to U, a distance of 90 feet. At U, a few yards of the lower system are free of rock and the channel is dissolved out sufficiently large to be entered. Immediately, however, the water passes into a low channel which cannot well be traversed. It passes underneath the higher tube-like channel above and leads off in a northerly direction. The water is not seen again until the two levels are merged through collapse at V, about 150 feet nearly due north of U. The two places are connected by the upper channel which follows a somewhat winding course of rather small diameter. It was traversed from U forward for a distance of about 70 feet to a pool of water. Later it was entered at V and traversed towards U to the same pool of water. The entire length of the passage is about 175 feet. The floor is scoured by the high waters which pass through the channel.

The system extending from V to Z was explored by entering the system at Z through the "Room of Fallen Rocks." The water issues from the lower level at V into a room developed by the collapse of the rock between the two levels which here are only a few feet apart. A block of rock 12 feet across and 20 feet in length occupies the floor of the room. The water passes about it on both sides. About 10 feet back in the tube-like upper level is a window-like opening in the floor through which the flowing water in the lower level may be seen.

The underground system from V to X is a complex system of low channels with rough floors and walls. The distance along the main channel is about 300 feet. The height varies from three to five feet and the width is from ten to 20 feet. Many small channels lead away or connect with the main channel. They are all occupied by water when the underground stream is slightly swollen by storm waters. Ragged pillars of rock between the passages are common. At W, the low-water stream leaves the main channel and follows a small low side route. At X, the waters return to the main channel by issuing noisily up through crevices and pothole-like openings in the rough floor. The channel, X-Y-Z, has a zig-zag course developed along intersecting joints. The passage is five to eight feet in height, eight to 12 feet in width, and 175 feet in length. The water flows noisily over the rough floor. At Y, a small tube-like channel comes in from the southeast. While it was not traversed, there is little doubt about its connection with the main system at Y_1, as indicated in the map, Fig. 3. At Z, the waters descend over the rough floor and into an enlarged joint crevice to a lower level. The fall through the crevice is about three feet. The total fall here is only about five feet. The joint crevice through which the water falls is not large enough to enter. The water falls on a roughened floor and flows westerly through a broad passage but little more than one foot high. Forward from the waterfall and about eight feet above, a small channel two or three feet in diameter leads off in a northwest direction. It was traversed about 150 feet, beyond which it was impossible to go.

The underground system extending from I to Z through the low-level channels has the appearance of being unfinished as compared to the main system. The waters passing through it play hide-and-seek through the rough low channels, some of which still retain the tube-like characteristics of underground channels developed below the water table. It is quite apparent that the underground stream has been diverted from the main system at I into the smaller and slightly lower system. The invasion of the river waters through the illy prepared lower route is so recent that the new route is not fully integrated. It still follows the network rather than any one continuous route through the network system. This network system is modified but little from its primitive condition as formed below the water table by groundwaters independent of the influx of surface waters diverted into it after the withdrawal of the groundwater to lower levels.

In summary the system described above and shown in plan in Fig. 3 consists of two diverging main channels which lead in somewhat different directions. The waters coursing through these channels enter them principally near the south end of the gulf close to the manhole-like opening in the western wall through which entrance into the system is gained. The shorter system leads northwest parallel with the western edge of the gulf. It is relatively simple. It is quite direct and has few connecting channels. Its traversed length is 715 feet, and the aggregate traverse of the main channel and the connecting channels totals 1,230 feet. The second main channel leads generally west away from the south end of the gulf, though its course is far from direct. It follows a zig-zag course, alternating chiefly northwest and southwest in conformity to two major intersecting joint systems. It is a complex channel system consisting of many minor leads which leave and return to or branch off from the main channel. Also it is developed at two distinct major levels with minor connections at still other levels. Water does not follow the main channel through the entire system, except during times when the underground stream is swollen by the storm waters of the surface system far to the east. The low-water stream is diverted from the main channel and follows a poorly developed system at a slightly lower level. In turn the diverted stream descends to a still lower level which it was impossible to follow. The main channel has a traversed length of 2,170 feet, and the entire system, left of the entrance opening, has an aggregate traverse totalling 4,945 feet. The aggregate traversed length of the entire system reached through the small opening in the western wall of the gulf is 5,175 feet.

Elrod Cavern and Underground Lost River. A round, steep-sided, collapse sinkhole, 90 feet in diameter, lies about 125 feet northwest of the north end of the Wesley Chapel gulf and about 400 feet south of the Elrod residence (see Fig. 3). On the north side of this flat-bottomed, abrupt sinkhole, a steep slope leads under the overhanging rock wall into a cavern known as the Elrod cave. It extends a little south of east for 350 feet and varies in width from 40 to 125 feet, except at the extreme eastern end where it ends in a narrow passage in broken-down rock. An outline of the cavern is shown in Fig. 3. Its width of 125 feet just east of the collapse sinkhole is rather remarkable. The cavern undoubtedly extends westward from the sinkhole, as the circular sinkhole is clearly a feature formed by the falling in of the rock which once formed the roof of the cavern. No openings can now be found through which entrance may be gained to the cavern system west of the collapse sinkhole, and nothing is known about it there.

The cavern is entered through a small opening about 15 feet below the flat bottom of the sinkhole. A steep inside talus slope composes a further descent of 15 feet to a clay-silt platform which forms a considerable part of the cavern floor. A deep trench with steep slippery sides extends along the north side of the cavern. The bottom of this trench is 16 feet below the level of the expansive mud floor. Apparently the mud floor is a platform built up by the clay silts which have accumulated in the cavern through repeated floodings at least to the height of the mud platform. A number of shallow trenches lead across the mud platform from the south side of the cavern to the trench and to a deep, funnel-shaped pit on the north side. It is quite evident that streams of muddy water at times pass across the mud floor in a northerly direction. The trench on the north side of the cavern begins in several small leads coming from talus rock about 110 feet nearly due east of the entrance into the cavern. It is evident that at times waters issue here and follow the trench for about 75 feet to its western end, where they disappear in holes in the loose rock. These waters appear to escape in a westerly direction through the rock litter which obstructs the western end of the cavern. On the sides of the slimy mud trench are many well developed mud stalagmites formed through the dropping of water from the roof on the mud surfaces (see Fig. 12). The sides of the funnel-shaped pit have recently caved in, and a tumbled mass of mud and mud clots form its steep sides. The upper edge of the pit is nearly vertical, and the perimeter of the pit is only roughly circular. The pit is 30 or 35 feet across. Its western edge is low and merges with the trench just west of it.

The mud platform south of the trench reaches nearly to the massive rock forming the ceiling of the cavern. South of the pit the ceiling is higher, reaching five to seven feet above the mud floor. The mud floor extends 175 feet eastward from the entrance of the cavern. It is terminated by an abrupt scarp of fallen rock which rises seven or eight feet above the mud floor. The mud platform in the cavern has an altitude of about 555 feet, and is about 50 feet beneath the surface of the field above. It is significant that this flood-formed platform is at least 15 feet below the level of the alluviated floor of the gulf just southeast of it. There can be no doubt that the shallow trenches leading across it are runways made by waters which have entered through leads directly connected with the gulf.

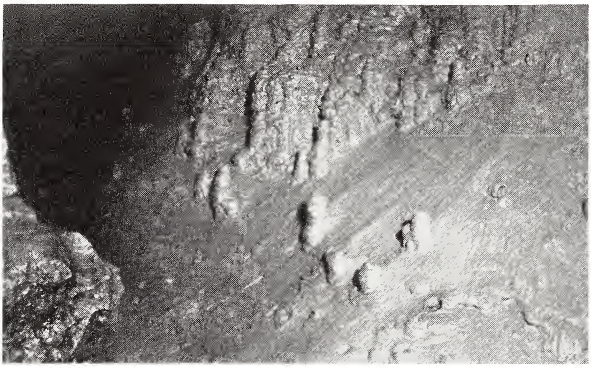

Fig. 12. View showing mud stalagmites on the side of the flood-water trench on the north side of the Elrod cavern, about 60 feet from the cavern entrance. Flood waters from Wesley Chapel gulf enter the Elrod cavern and flood a considerable portion of the floor. The mud stalagmites have a peculiar origin.

Water seeping through the ceiling has formed numerous stalactites which hang as slender pendants or in massive clusters from the cavern roof. The drip on the mud floor has formed many scattered small stalagmites and occasional thin plaques of calcite which scarcely rise above the mud floor. Several nests of cave pearls were found where the drip from the ceiling has been responsible for the formation of angular to rounded discreet structures in shallow pools on the mud surface. Most of these structures resemble slightly rounded angular pebbles, but they have been built up of calcite in concentric layers, much like the structure of oolites. Many of them are hollow or porous inside, and some have calcite crystals partly filling the interior. Some of them in the middle of the nests, where the drops of water fall directly on them, have been beautifully polished by the motion against one another caused by the falling drops of water. Those at the outer margins of the nests are much larger, more irregular in shape, and have a rough, burr-like surface. Recently Hess (1929) and Davidson and McKinstry (1931) have discussed in some detail the nature and origin of these little known structures.

South of the deep pit a low-roofed channel partly blocked by masses of fallen rock leads southward and directly under the gulf at the northwest corner (see Fig. 3). It has a mud floor, and current marks indicate quiet clearly a northward flow of the flood waters which at times come from the gulf. Another broad channel with a rock-covered floor and a low ceiling leads south for a distance of 65 feet from the main cave about 30 feet east of the scarp made by mass of fallen rock near the middle of the cavern. This low channel is about 30 feet in width. It terminates in a mass of broken rock under the northern edge of the gulf. Rill marks are present on the floor where waters enter this channel from the gulf during high-water periods. These rills become lost under the masses of fallen rock composing the rocky platform and lying upon the mud underneath.

The rocky platform upon which occur many well-formed conical stalagmites is seven or eight feet above the mud floor of the western part of the cavern. The floor is very rugged and irregular. Small pools of clear water in rimstone basins are perched here and there on the rock masses, the water having accumulated from the drip from the roof. The ceiling is seven to 15 feet above the irregular floor and is beautifully decorated with stalactite pendants. The cavern extends a little south of east for about 175 feet beyond the scarp marking the western edge of the fallen rock mass. The width varies from 40 to 60 feet to near the end. The eastern extremity rises up over fallen rock and ends in a narrow passage of broken-down rock. The terminus is along the northern edge of the gulf near the level of the alluviated floor, and just west of the old quarry. Tree roots penetrate the rocky mass at the very eastern end of the cavern.

About 75 feet beyond the western end of the rocky platform, near the middle of the cavern, the north wall of the cavern is well separated from the platform floor of the cavern. The opening here leads down some 20 feet under the overhanging north wall to a muddy cavern channel which comes from the east. This channel leads north about 15 feet and then turns to the left in a westerly direction. The passage coming from the east is directly connected with an underground stream at a slightly lower level which may be seen through a muddy opening under the overhanging rock. This underground stream remained undiscovered by the writer until December 1, 1931, after much of this paper had been written. Only about 20 feet of the underground stream is visible through the low opening. On the two ocasions that this stream has been seen by the writer, it was about 10 feet wide and one foot or more in depth. It was flowing rather swiftly in a northwest direction nearly parallel with the northern wall of the cavern. It was not entered, as its roof is rather forbiddingly low. Its exploration must await more favorable conditions than the rather high-water period and the winter weather of December impose. The altitude of the underground stream is about 535 feet. It is, therefore, about five feet lower than the low-water level of the water of Lost River in the pit at the south end of the gulf.

There is little question about this stream being part of the underground system of Lost River. It very probably branches off the underground stream east of the rise in the gulf and follows a course about the gulf along the east side and around the north end. It is quite likely that the swallow-holes in the cluster at the end of the overflow channel on the eastern side of the gulf floor connect with this underground stream. During high-water periods the waters of this stream rise between the gulf wall and the mud platform and flow through the muddy passage leading west, some seven or eight feet higher than the underground stream. This passage is about eight feet wide and three feet high. It follows a winding westerly course for about 130 feet, where it connects with the trench and pit along the north wall in the western part of the cavern. Its connection here clearly indicates the source of the waters which flood the trench during periods of high water both in the gulf and in the cavern which are so intimately connected.

CONCLUSION

In this paper an attempt is made to give the general setting of the Lost River karst region and to present the details of a section of the underground stream system in a locality where it is available for study. The presentation of the details is prefaced by defining karst and identifying the individual features which compose the karst assembly in the Mississippi valley areas which exhibit in a marked degree the features peculiar to underground drainage in limestone regions. The underground system described in considerable detail is largely available for exploration and study because of its connection with a gulf which in itself is one of the most outstanding individual features of the Lost River karst region. The Wesley Chapel gulf and underground Lost River in its vicinity are in themselves of sufficient interest to merit description independent of the principles which they teach in the developmental history of karst features. The carefully prepared map which accompanies this paper presents many of the details and relations which are discussed in the text. The work necessary for its preparation has been great, but it is believed that this map is as essential as the text itself. It is the writers' intention to present at some future time the full details of the Lost River karst area, as many other localities have features of instructive interest in the behavior and in the product of a river that runs many miles underground. No other locality, however, has been more interesting and instructive than the Wesley Chapel gulf and the underground river system in its vicinity. Certain developmental phases of the gulf and the underground course of the river may be presented as the conclusion of this paper.

Wesley Chapel gulf as a surface feature represents the destruction and removal of 720,000 cubic yards of native limestone, an amount equivalent to a block of limestone 1,000 feet long, 300 feet wide, and 65 feet thick. The void created by the removal of such a prodigious amount of rock has been filled to a depth of 30 feet over the bottom by the deposition of 275,000 cubic yards of alluvial silt. The void remaining is a depression averaging 1,000 feet long, 325 feet wide, and 38 feet deep. It was once occupied by 445,000 cubic yards of limestone rock. This abrupt, level-floored depression is remarkably symmetrical in outline. Both ends are equally round. They are semicircles of equal radii. Both ends are of slightly greater breadth than the middle section between them. The length is approximately three times the width. The long axis conforms in direction almost exactly with a major joint system in the rocks from which the feature has been cut. This is not without certain significance.

The width of the gulf is far greater than any known section of the underground channel of the river with which it is related. It is not merely a fallen-in cavern channel whose collapse rock has been dissolved away. The shape of the gulf and its present relations to the underground water courses suggest something of the nature of its development. It very probably was initiated as a small feature of collapse over a broad and weakened portion of the underground stream system. Overbroadening and consequent collapse very likely may have resulted from the dissolving out of rock walls between parallel underground channels. After such initial collapse the underground stream would find passages about the sides of the collapsed rock, and solution and removal of the walls about the collapsed material would undermine the walls. In time further collapse would increase the perimeter of the collapse depression. It is readily conceivable that two or three collapse areas may have formed in a row. Through increase in their perimeters they would eventually merge to form an enlarged depression in common with semicircular ends, such as Wesley Chapel gulf possesses. Horns of rock would for a time extend out into the gulf floor area, but in time they would melt away. One such horn of rock, tumbled and broken, still protrudes into the general floor area of Wesley Chapel gulf.

Wesley Chapel gulf is unusually symmetrical in outline. It may not always remain so. An underground stream swings around under the south end. Further growth through collapse is undoubtably taking place there, but it is at such a place that the symmetry is maintained. The underground system just west of the south end, however, is promoting a marked growth in this direction, and growth here will interrupt the present symmetry. At the north end of the gulf, a cavern carrying the flood waters of the subterranean stream has developed an enormous width and is in the process of collapse. Eventually the gulf will be united with the circular collapse feature through which entrance to Elrod cavern is gained. Even in this cavern an underground stream is carrying on a sapping action under the northern wall. This same underground stream no doubt is enlarging its route along a part of the eastern margin of the gulf. The entire present gulf is surrounded by active underground streams. Water cannot get through the compact and insoluble alluvial silt of the gulf floor. It must find its way about this built-up barrier through the fallen rock along the base of the walls and between the walls and the fallen rock, exactly as it does in the excellent example exhibited from A to B just inside the manhole-like opening in the west wall of the gulf. Or it follows small passages along joints which in time are greatly enlarged. When a mass tumbles in from the gulf perimeter, the dissolution of the broken rock goes on apace. Wesley Chapel gulf is thus a product of progressive perimeter collapse and dissolution of the fallen rock. The enveloping underground streams are thin but vigorous dissolving machines which insidiously sap the foundations of the gulf walls. These walls are hollowed out and weak at their bases. They do not stand on solid rock. 720,000 cubic yards of rock have been undermined, tumbled in, dissolved away, and a new level created. The process of rim enlargement of the gulf will eventually extend the gulf to such proportions that the underground stream will cut a channel through the alluvial floor which then will mark a change from that of a gulf feature to that of a valley. It will become elongated and pass into a valley expanse. The floor level will merge with other surfaces to form an integrated valley system open to the light of day. A gulf is a temporary feature in the karst cycle of land destruction which marks a beginning of the uncovering of an underground stream and the development of a valley.

It is conceivable that underground Lost River follows a simple underground conduit from the sink to the rise. The fact that the series of major swallow-holes along the dry-bed, the momentary appearance of the stream in the Wesley Chapel gulf, and the single rise south of Orangeville are nearly in a direct line gives weight to this conception. No such simplicity, however, is revealed in the map of the system in the Wesley Chapel gulf locality. Instead, it is a very complex system, consisting of a series of anastomosing channels which conform in the main to two intersecting joint systems directing the waters chiefly in alternate northwest and southwest directions. The complexity is even greater than the network pattern itself suggests. A great difference in volume exists between low-water and high-water periods. This gives opportunity for routes to be occupied during high-water periods that are not reached during low-water periods. Thus, there is an anastomosing of channels in a vertical direction as well as a horizontal. During low-water periods small and poorly developed passages at slightly lower levels may be followed instead of the broad, open passages at slightly higher levels. Such a condition is excellently illustrated in the system west of the gulf, and it has been described in detail.

No doubt the presence of the gulf has considerable influence on the development and maintenance of more than a single passage. All collapse features tend to pond or impede the stream waters and force them to rise to higher passages. There is little doubt about the waters of Lost River passing both to the north and to the south of the gulf. But the waters, after escaping about the gulf around the south end, go in two directions in a passage, even in low-water periods. This divergence is not to be charged to the influence of the gulf, as it takes place below it. The diversion of the waters to the low, poorly developed system at I, 500 feet west of the gulf, is in no way connected with an impediment. It must be acknowledged, however, that diversions very probably exist because of rock falls and consequent ponding in the undergrounding system.

The network system of underground Lost River has been cited by Davis (1930, 540-542) as evidence of development of caverns below the water table. The writer agrees with this view most heartily, but he would have the chief excavational development take place after the system became the route of discharge of the river waters from the surface, rather than that it took place chiefly during a long period of solutional development below the water table. The network system may be attributed to the following five factors: *First*, the dense and well-bedded limestone of the karst terrain is traversed by two intersecting joint systems. The bedding planes and the joint fractures are permissive planes or thin passageways along which percolating groundwaters may go. Groundwater percolation is practically nil through the dense beds themselves. Movement is therefore confined to the joint systems and the bedding planes. This is a fundamental and all important factor. The character of the network system is determined by these predetermined permissive planes. *Second*, groundwater percolation and movement below the water table have dissolved out connecting three-dimensional systems sufficiently large to permit free flow of waters through them. It is not believed that these water-filled systems are fully integrated into flow or stream systems. They are embryonic passages only. They are larger and more systematically developed in certain beds which are more readily soluble than others. When the water table is lowered to them, then they may serve as a network system into which vadose waters may enter and follow in accordance with the fortuitous development of the primitive network system. *Third*, the network is maintained above the water table by flood waters which rise in the system and follow all channels open to them. Were it not for floods certain runways would become integrated into a relatively simple system, as certain passages would be developed which would carry all the stream waters and others would not be developed beyond their small and poorly integrated condition attained while below the water table. Flood waters, however, fill all of them up to the limiting heights of the floods and develop the network as a whole. *Fourth*, as the surface drainage is lowered the water table also is lowered, and slightly lower primitive routes are taken over by the invading streams. The earlier well developed passages are left at slightly higher levels and are used only during high-water periods. Eventually the earlier well developed routes are left as dry caverns. *Fifth*, ponding of the underground system behind barriers, such as collapsed superincumbent rock, or gulfs, cause waters to develop or follow other passages. This factor is local in the system and is far less important than floodings by storm waters which reach high levels throughout the system.

Thus the network system is a natural consequence of a number of factors imposed on an underground system which flows long distances beneath the surface. A simple conduit would be more difficult to explain under the conditions imposed in the Lost River system than the complex network which it possesses. All of the factors enumerated in the above paragraph are well illustrated in the underground system in the Wesley Chapel gulf locality.

Another feature of the underground system of Lost River which deserves discussion is the relatively great width as compared to the height of the channels. The main channels are usually from two to three times wider than they are high, and certain stretches have a nearly continuous width of five to eight times the height. Sections B-F, V-X, O-T, and R-S of the mapped system, Fig. 3, are examples of relatively low ceilings and great width. Three factors appear to be influential in the attainment of relatively great width and little height. First, certain beds are undeniably more soluble than others. These beds are the chosen zones in which a better integrated system is developed beneath the water table long before their invasion by surface stream waters. A zone 10 to 20 feet below the Lost River chert and near the contact of the St. Genevieve and St. Louis limestones is conspicuously ramified by underground channels in the karst region of southern Indiana. Other zones below in the St. Louis limestone are also conspicuously channeled out. Lost River is developed at several levels which are connected with abrupt descents and ascents. The highest of these levels is in the very top of the St. Louis limestone, about 15 or 20 feet below the Lost River chert of the St. Genevieve limestone. At least two other levels lower in the formation are occupied by the river system for considerable stretches. Two of these major levels are present in the mapped system at the Wesley Chapel gulf.

A second factor which favors width development is the development of the underground system near the water table the westerly slope of which is very gentle. Bottom erosion is not conspicuous. The nearly water-filled section, O-T, at the end of the explored main channel system west of Wesley Chapel gulf, is an excellent example of the course at the very level of the water table. The water here is practically without flow except during high-water periods. The height of the channel is about five feet, while the width is 30 to 40 feet. During high-water periods great quantities of water are forced through the system here. The low roof is washed with as much force as is the floor. The great width of the channel is probably because of more ready solubility of the limestone. Depth attainment by bottom erosion is certainly very little.

A third factor which is of some influence in the lack of height development is the tendency of the underground stream to vacate a channel level whenever a slight lowering of the water table takes place. The underground stream enlarges and develops the routes open to its flow at or near the water table. Primitive undeveloped systems are ready to take some of the rivers waters when the water table approaches their levels. Waters enter at some favorable vertical connection or opening and gradually vacate the higher level while the lower level is being developed larger. Floor erosion of the upper level thus is not permitted to take place for long periods of time. The river literally changes floors too frequently for any considerable depth attainment by floor sculpture. During floods floor sculpture will take place on all the levels occupied. A good example of three levels with communicating holes connecting them is found in the Chas. T. Brown cavern between the Turner and Tolliver swallow-holes.

Three rather broad levels are present within a vertical space of 45 feet. High waters flow through all three of them. Perhaps floor erosion is of somewhat less consquence because of the distribution of the erosion to the network of floors instead of it being confined to a single floor.

Underground Lost River is a stream system beneath the surface which occupies a network at three or more levels. The waters in the system are chiefly waters which have invaded the system from the surface. They have deserted a long stretch of a surface system almost completely. The master surface stream leaves its well developed surface channel and passes underground many miles before coming to the surface. This stream has developed beneath the surface a subterranean system sufficiently large to justify its appellation of underground river. Only a little of its underground system is known. Much of the little that is known about it has been presented in this paper.

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CLIMATE AND CORN YIELD IN INDIANA, 1887-1930

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The concept of climatic limits and optima is not new. As regards corn or maize, such determinations have, however, been made only within rather wide limits. Cold and dry limits have received most attention with little mention of optima. Finch and Baker say: "Practically no corn is grown where the mean summer temperature is less than 66°F. or where the average night temperature during the summer months falls below 58° F. The climatic boundaries of the region of greatest production in the U. S. are a mean summer temperature of 70° to 80°, a mean night temperature exceeding 58°, frostless season of over 140 days and an annual precipitation of 25 to 50 inches of which 7 inches occur during July and August."[1] The present investigation is an attempt to gain more definite information as to the effect of several climatic factors on the yield of corn in Indiana.

The method herein employed is not new to climatology. Dr. Griffith Taylor of the Department of Geography, University of Chicago and Dr. Ellsworth Huntington of Yale University have employed variations of it. The method consists of plotting one factor, July rainfall for example, on the abscissas and the other factor on the ordinates. At the meeting point of the two factors for that year is located the yield for that year. The yield for each year covered by the problem is thus located. Only by a double smoothing can order be brought out of the chaos of the first figure. The smoothed yields are then placed on the diagram and shaded progressively lighter to represent progressively lower yields. State averages were used if available, otherwise data from the Indianapolis station sufficed.

This method, applicable to many other investigations, would seem to have some advantages over correlation coefficients in that the resulting information is visual and more easily and rapidly interpreted by most people. The disadvantage of this method is that only two climatic factors can be considered on one diagram.

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[1] Finch and Baker. "Geography of the World's Agriculture." p. 29.

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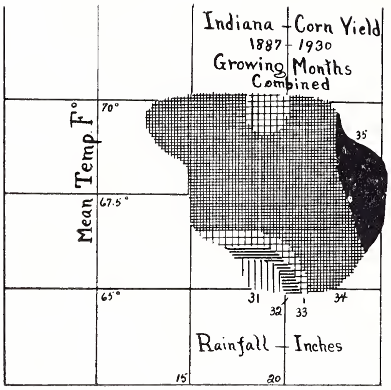

Fig. 1. Evidence is given that our material must be broken up in smaller parts for analysis.

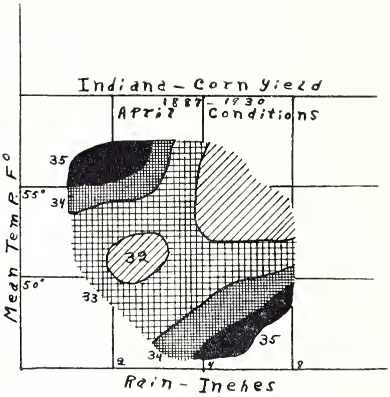

Fig. 2. April, it seems, should be either cool and moist or warm and dry for best yields. If rainfall for April is less than three inches temperatures above 55° give best results. For greater rainfall, a temperature below 50° gives highest yields.

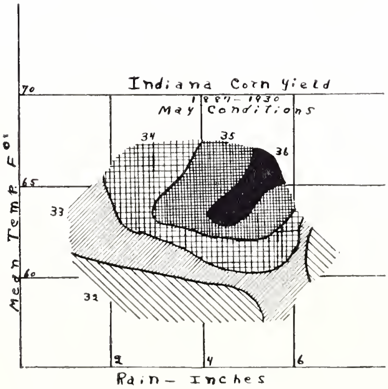

Fig. 3. A warm moist May is best. Temperatures above 63° and over four inches of rain give best yields. Rain and temperature seem to have about equal effect on the higher yields.

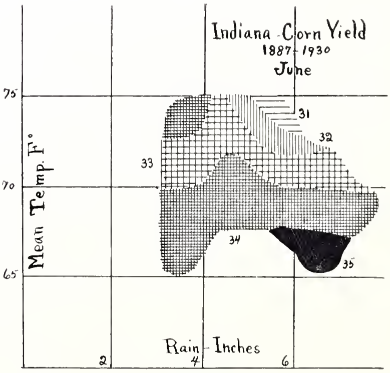

Fig. 4. A cool moist June gives highest yields. The temperature should be below 70° and the rain at least three inches. Even better yields result if the temperature is below 68° and accompanied by a rainfall of more than five inches.

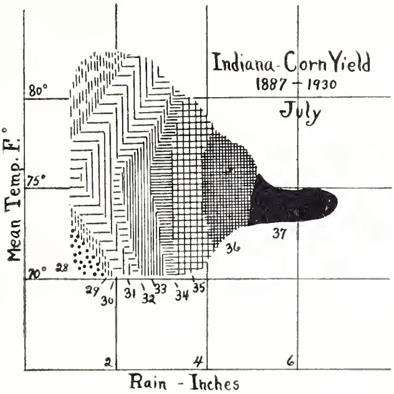

Fig. 5. If July has more than 3.38 inches average rainfall for the state, rain is the controlling factor, over five inches giving the best results. If rainfall is less than average, temperature plays an equal part; temperatures either higher or lower than 75° to 76° give lower yields.

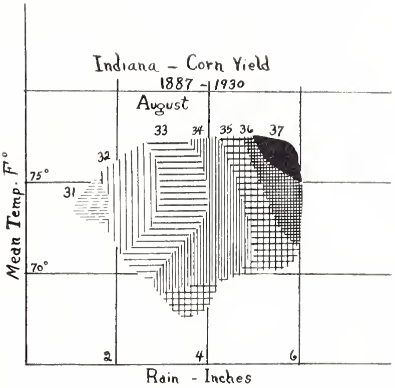

Fig. 6. A warm moist August gives highest yields. Rainfall should be at least five inches and mean temperature at least 72°; yields are even beter if the mean temperature is 75° to 76°. Rainfall is, however, of more importance than temperature.

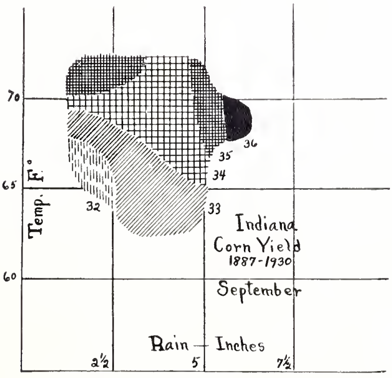

Fig. 7. The yield is highest if September has a temperature of at least 67° with over five inches of rain. If above 70° in mean temperature, a dry September is also highly productive.

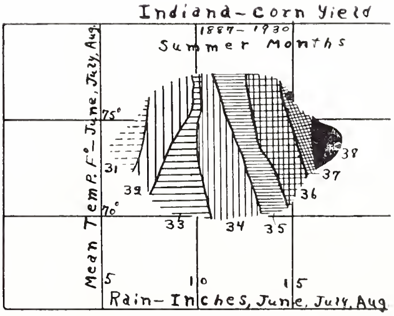

Fig. 8. A mean temperature for the three summer months of 73° to 75° and at least 15 inches of rainfall for these months give the greatest yields.

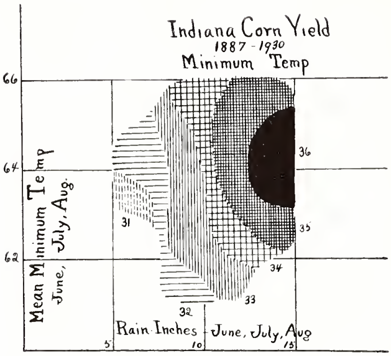

Fig. 9. Mean minimum temperatures of summer have often been given as important to yield. This figure shows that the best yields are accompanied by mean minimum temperatures of 63° to 65° though another degree either higher or lower makes little difference.

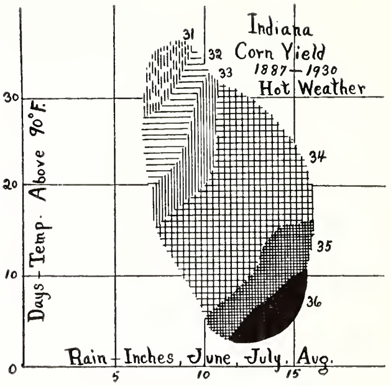

Fig. 10. Extremely warm weather is injurious to corn yield. Such hot days have as great an influence as does rainfall. An increase in the number of such days from 10 to 20 even with the same amount of rainfall may decrease the yield notably.

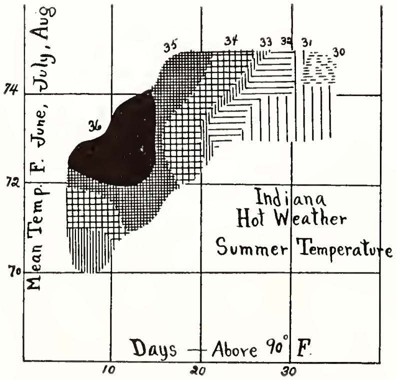

Fig. 11. Hot weather compared with mean summer temperatures shows that a mean summer temperature of 72° to 74° with not more than 15 days with temperatures above 90° gives best results. Lower mean temperatures decrease yields as does an increase in the amount of hot weather.

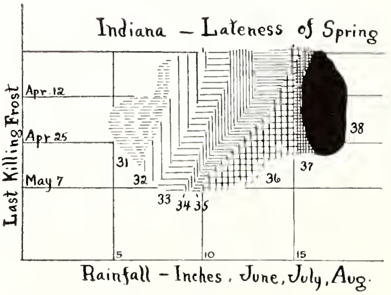

Fig. 12. Contrary to usual opinion, conditions accompanying late spring frost favor a high yield of corn, especially if the summer has only the normal summer precipitation of about 10 inches for June, July and August.

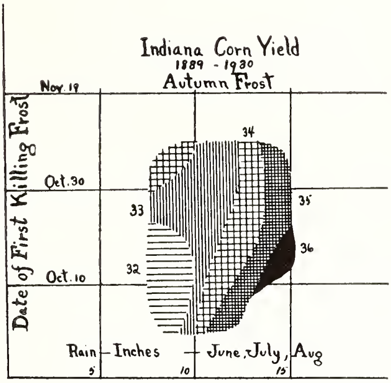

Fig. 13. An early frost in the fall is favorable if the season has been normal or above as regards rainfall.

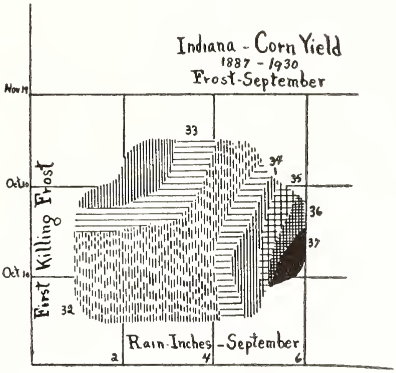

Fig. 14. A frost not later than the average frost date of October 20 is beneficial, especially if September has been abnormally wet.

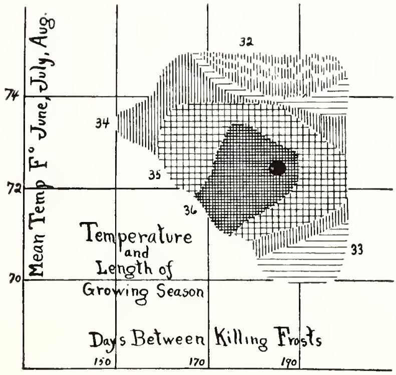

Fig. 15. A mean summer temperature of 71° to 73° and a growing season of 170 to 190 days is here shown as giving the highest yields.

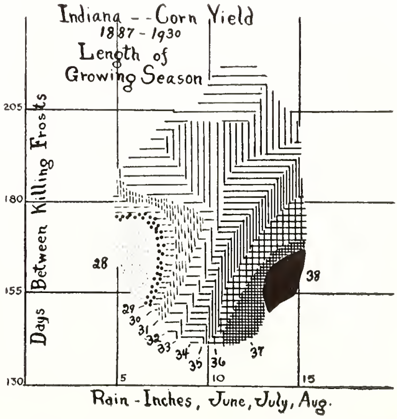

Fig. 16. Low yields result from short dry seasons, medium yields from long seasons having either much or little rain and high yields result from short moist seasons.

STRATIGRAPHIC PROBLEMS INVOLVED IN DETERMINING THE GEOLOGIC STRUCTURE IN THE LOWER MISSISSIPPIAN OUTCROP AREA OF SOUTHERN INDIANA

PARIS B. STOCKDALE, Ohio State University

Introduction. At places in the outcrop belt of lower Mississippian rocks in southern Indiana, geologic structure is difficult to ascertain from a survey of the areal geology because of certain perplexing and confusing stratigraphic relations. Some of the data gathered for structural purposes have been incorrect as a result of failure to appreciate the nature of certain stratigraphic problems and to recognize the correct age and correlation of certain beds. One complex group of rocks, the Borden (Knobstone), has been more or less avoided in the past because of lack of sufficient acquaintance with details of the stratigraphy. Recent intensive study of the stratigraphy of the Borden and associated lower Mississippian formations of southern Indiana has brought to light several stratigraphic horizons which may be used as keys for geologic structure determinations. The same study has also revealed some perplexing and significant stratigraphic situations which should occasion caution on the part of the worker on geologic structure.[1] The aim of this paper is to clarify some of the confusion which has arisen from the misunderstanding of some of the more important stratigraphic problems. No attempt is here made to treat the subject fully.

STRATIGRAPHY OF THE LOWER MISSISSIPPIAN ROCKS OF INDIANA

The Stratigraphic Column. The stratigraphic column involved in this study consists of Mississippian formations which lie beneath the Salem limestone. In the classification of the Indiana Division of Geology these formations are all considered older than Meramecian. This classification is in harmony with the views of Keyes (1892), Weller (1908, 1914), Cumings (1922), and others. Accordingly the Warsaw (Harrodsburg limestone in Indiana) is placed with the Osagian, rather than with the Meramecian above, as it was placed by Ulrich (1911), Butts (1915, 1918, 1922), and Weller (1920). Controversy over the classification of the Warsaw was reviewed fully by Cumings in 1922.[2]

The following is a list of the lower Mississippian units in Indiana which are older than the Salem limestone:

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[1] Stockdale, Paris B., The Borden (Knobstone) rocks of southern Indiana: Indiana Dept. Conservation, Div. Geology, Pub. 98, 1931.

[2] Cumings, E. R., Nomenclature and description of the geological formations of Indiana: Indiana Dept. Conservation, Div. Geology, Handbook of Indiana Geology, pt. 4, pp. 475-486, 1922.

Harrodsburg (Warsaw) **Limestone**
- Upper Harrodsburg
- Lower Harrodsburg
    - Guthrie Creek member
    - Leesville member
    - Ramp Creek member

Borden (Burlington-Keokuk) **Group**
- Edwardsville formation, with the following members locally:
    - Mt. Ebel member
    - Dry Creek member
    - Weed Patch member
    - Cutright member
    - Brownstown Hills member
- Floyds Knob formation
- Carwood formation, with the following members locally:
    - Finley Knob member
    - Lampkins member
- Locust Point formation
- New Providence formation, with the following member locally:
    - Kenwood member

Rockford Limestone

Only brief descriptions of the more important units listed above can be offered here.[3] The surface distribution of the Mississippian rocks in Indiana is indicated on Plate 1. Classification and geologic sections are shown on Plate 2.

Lowest Mississippian Formations. Since Kindle's 1899 correlation the entire New Albany shale has been generally considered by Indiana geologists as being of late Devonian age. Slight doubt exists, however, as to the truth of this in the light of numerous stratigraphic studies which suggest an early Mississippian age for at least a part of the black shales (New Albany, Ohio, Chattanooga) in Kentucky and Tennessee. Quite recent contribution to this problem was made by Savage and Sutton, who showed by faunal studies that the upper part of the black shale in south-central Kentucky is of early Mississippian age.[4] If the upper part of the New Albany shale of Indiana is Mississippian in age then it is the oldest Mississippian representative in the state.

Lying immediately above the New Albany shale in southern Indiana is the Rockford limestone, commonly referred to in the early literature as the "Goniatite limestone" or "Rockford Goniatite limestone." It is this formation that has been generally regarded as the oldest Mississippian unit in the state. It ranges in thickness from one to three feet. It has very constant lithologic characteristics. It is a firm brittle limestone with an almost lithographic texture. The fresh stone is gray in color, mottled by distinctive green specks and streaks. Because of its ferruginous quality the stone is yellowish brown on weathered surfaces. As a result of

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[3] Complete descriptions of the formations are given in the previously mentioned Indiana Geological Survey publication. See footnote no. 1.

[4] Savage, T. E., and Sutton, A. H., Age of the black shale in south-central Kentucky: Am. Jour. Sci., 5th ser., vol. 22, pp. 441-448, **1931.**

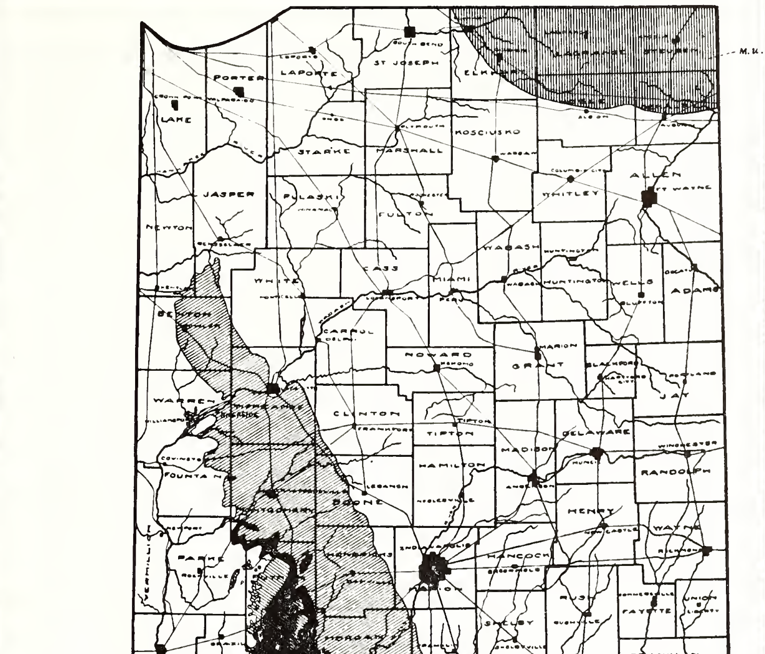

PLATE 1

Map showing surface distribution of Mississippian rocks in Indiana. (After Cumings, 1922.)

Kindle's 1899 studies the Rockford has been regarded as the "sole representative of the Kinderhook" in Indiana. Kindle (1899), Butts (1915), Cumings (1922), and others have called attention to the absence of the Rockford limestone south of the Ohio River. Kindle was of the belief that it is represented by the basal New Providence shale, whereas Butts held that the Rockford absence strengthens the testimony of an unconformity between the New Albany shale and the New Providence shale.

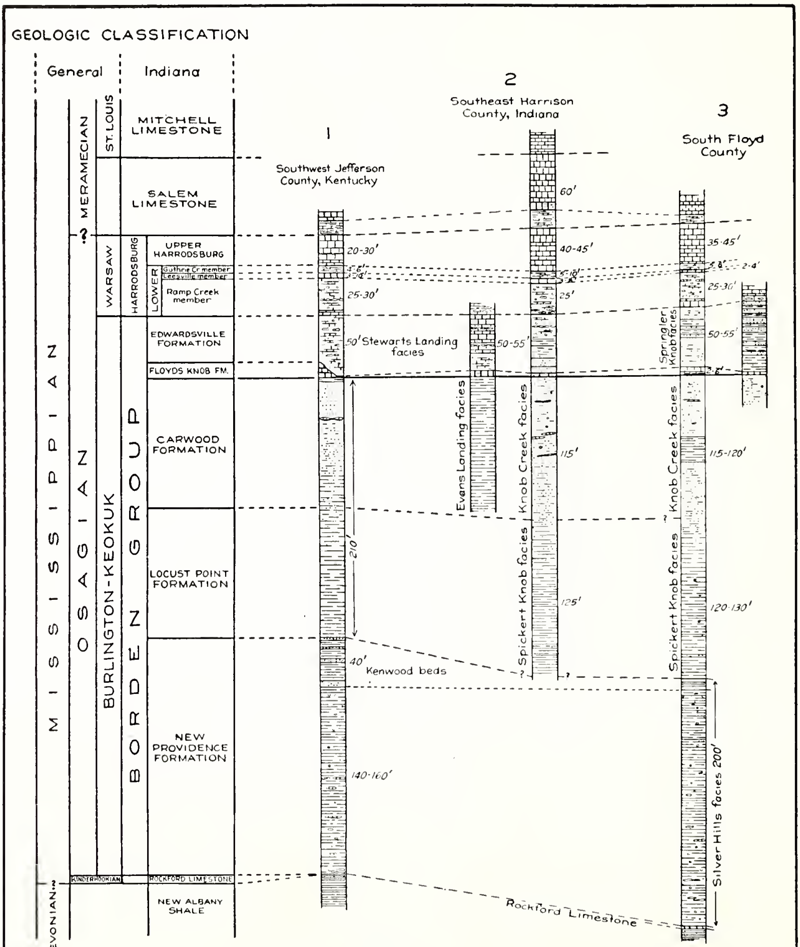

PLATE 2

Classification and geologic sections of lower Mississippian rocks in part of southern Indiana. (After Stockdale, 1931. Courtesy Indiana Department of Conservation, Division of Geology.)

Borden Units and Facies. The Borden group of Indiana comprises the lower Mississippian rocks between the Rockford limestone beneath and the Harrodsburg limestone above. Prior to 1922 when Cumings proposed the name "Borden,"[5] the rocks were designated by the term "Knobstone." The thickness of the unit in its unglaciated outcrop area of Indiana ranges from some 400 feet at the south to 765 feet at the north. The Borden rocks are mainly clastic—fine-grained sandstones, siltstones, and shales. Variations from the clastic type are: (*a*) the calcareous facies of the thin Floyds Knob formation; (*b*) the prominent bioherms and certain local members and facies of the Edwardsville formation; and (*c*) occasional thin calcareous layers and patches found irregularly distributed thruout the group. At most places in Indiana the Borden group is sharply delimited both below and above, and is markedly dissimilar in lithologic characteristics from the underlying and overlying strata. The most notable exception is in southeastern Harrison County, Indiana, and adjacent Jefferson County, Kentucky, where the topmost Borden formation (Edwardsville) is a calcareous facies quite similar to the overlying siliceous limestone of the Harrodsburg. This exception presents one of the significant situations to be discussed more completely later.

The lowest formation of the Borden group, the New Providence, is mainly argillaceous shale or claystone, ranging in thickness from 190 to 290 feet in southern Indiana. South of the middle of T2S, R6E, east-central Floyd County, Indiana, occasional resistant sandstone beds, with thicknesses up to about two feet, lie within a 20-foot interval at the top of the New Providence shale. These sandstone layers are Indiana's representative of what in Jefferson County, Kentucky, has been named by Butts "Kenwood sandstone."[6]

The Locust Point formation which lies above the New Providence shale is mainly a massive or shaly siltstone in the southern part of the Indiana outcrop area. Northward the formation becomes a succession of fine-grained sandstone beds and alternating shaly zones. Fossils are rare, aside from worm marks. The average thickness of the formation is about 125 feet. The overlying Carwood formation is much more complex. At the south, in Indiana, it is at most places a massive, fine-grained sandstone or siltstone. Here and there a silty facies displays a shaly appearance where weathered. The formation is highly fossiliferous at some localities; most commonly, however, it is lacking in fossils other than worm marks. The fossiliferous patches of the sandy facies of the southern area carry a fauna characterized by large brachiopods, with *Syringothyris textus*, *Orthotetes keokuk*, and various species of *Productus* prominent. The more silty facies, where fossiliferous, are featured by abundant bryozoans, mainly species of *Fenestella*, *Polypora*, *Cystodictya*, *Pinnatopora*, and *Rhombopora*. In the northern part of the unglaciated outcrop area the Carwood formation displays a number of lithologic facies varying from argillaceous shale and shaly siltstone to a bedded succession of thin resistant sandstone beds and shaly layers. Locally, abundant bryozoans occur in patches in the argillaceous phases. The more sandy sediments are practically devoid of fossils, aside from worm marks and *Taonurus* which are locally profuse. The Carwood formation ranges in thickness from 105 to 250 feet.

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[5] Cumings, E. R., Op. cit., p. 487.

[6] Butts, Charles, Geology and mineral resources of Jefferson County, Kentucky: Kentucky Geol. Survey, ser. 4, vol. 3, pt. 2, pp. 148-150, 1915.

The Floyds Knob formation is the key unit in subdividing the upper Borden rocks and correlating the units of southern Indiana with those of adjacent parts of Kentucky. This formation exhibits several lithologic facies. The most common is a limestone which varies markedly from place to place. Throughout the southern half of the unglaciated Indiana outcrop belt, and in adjacent parts of Jefferson County, Kentucky, the formation varies from fairly pure crinoidal, oolitic, or crystalline rock to ferruginous, siliceous limestone. The thickness averages from 3 to 4 feet. In Jefferson County, Kentucky, and adjoining regions, the formation is the one described by Butts as the "layer of oolite" and "oolitic limestone" at the "base of the Warsaw."[7] Locally, in southern Indiana the formation is a sandstone. North of T6N in Indiana, the formation is a peculiar mixture of calcareous, ferruginous, cherty, shaly rock. Extending upward from this, locally, and involving the basal portion of the overlying Edwardsville formation, are the prominent bioherms of the Edwardsville formation, mainly in Monroe and Morgan Counties, Indiana.

The Edwardsville is in many respects the most unique of all Borden formations. It displays the greatest thickness range—40 to 200 feet. It is predominantly a formation of shale, siltstone, and sandstone. A perplexing calcareous lithology at the extreme south end of the Indiana outcrop area and in adjacent Kentucky renders it easily confused with the basal member of the overlying Harrodsburg limestone. Geologic sections for southern Floyd County, southeastern Harrison County, and southwestern Jefferson County, Kentucky, are indicated on Plate 2.

Harrodsburg Limestone. The Harrodsburg limestone lies on top of the Borden group. It is divisible into two main stratigraphic units, the Lower Harrodsburg and the Upper Harrodsburg. In the first are recognized three distinct subdivisions, or members—the Ramp Creek member, the Leesville member, and the Guthrie Creek member.[8] One of these members, the Leesville, is especially valuable as a key horizon for determining geologic structure.

To one who has made regional observations, the Harrodsburg at once appears to be of a two-fold nature: (1) a lower part, which is in the main very impure and variable, characterized by numerous geodes, much chert, and irregularly spaced crinoidal layers, one of which is persistent; (2) an upper part of fairly pure limestone in the main, in places highly crystalline and often quite fossiliferous. The contrast in lithology between these two units might be considered sufficient to warrant calling each division an independent formation.

The Lower Harrodsburg includes all the irregular and variable impure rock lying between the top of the Borden and the base of the overlying, fairly massive, more regular limestone. Except for interbedded crinoidal lenses, this division is mostly a highly siliceous, fine-grained, brittle stone, known to the quarryman as "bastard rock." In places it may well be called a fine-grained calcareous sandstone. Where fresh it is light gray to blue-gray in color. A high iron content gives it a characteristic buff to yellow color where weathered. This siliceous phase is quite brittle, and upon weathering splits up into irregular flattened chips, broken off in a direction diagonal to the bedding. These same features are in part characteristic of the calcareous facies of the Edwardsville formation in southeastern Harrison County, and in the adjacent parts of Kentucky. In some places the rock is quite shaly. Stylolite-seams are not common because of the impure nature of most of the rock. Chert, varying in amount, is usually abundant, occurring as nodules and lenses, sometimes as heavy ledges, white to buff in color. A part of the chert is silicified crinoidal limestone. Geodes are a characteristic feature. They are also found in the underlying Borden strata, where they are generally much smaller and less numerous.

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[7] Butts, Charles, Geology and mineral resources of Jefferson County, Kentucky: Kentucky Geol. Survey, ser. 4, vol. 3, pt. 2, pp. 157-158, **1915**; Descriptions and correlation of the Mississippian formations of western Kentucky: Kentucky Geol. Survey, p. 26, 1918 (1917 on title page); The Mississippian series of eastern Kentucky: Kentucky Geol. Survey, ser. 6, vol. 7. p. 73, **1922**.

[8] Stockdale, Paris B., Stratigraphic units of the Harrodsburg limestone: Proc. Indiana Acad. Sci. for 1928, vol. 38, pp. 233-242, **1929**; The Borden (Knobstone) rocks of southern Indiana: Indiana Dept. Conservation, Div. Geology, Pub. 98, pp. 301-311, **1931**.

Interbedded within the Lower Harrodsburg, and in a few places forming a large part of it, are hard, resistant crinoidal lenses, ranging from a few inches to as much as eight feet in thickness. One crinoid layer near the top is persistent and gives a basis for subdividing the unit into its three members. This crinoid layer is the previously mentioned Leesville member. This member is everywhere a fairly hard, pure, blue-gray to whitish crinoidal limestone. In many sharp ravines it produces an overhanging bench and waterfall. It ranges in thickness from one and one-half to eight feet, with an average of about four feet. Extensive study has revealed a peculiar but distinctive shaly, siliceous, calcareous zone, which weathers buff to yellow, immediately above the Leesville limestone, and between it and the overlying "typical" Harrodsburg limestone of the upper division. This zone ranges in thickness from two to 10 feet with an average of about five feet. It is the Guthrie Creek member. Beneath the waterfall-forming Leesville member is most of the variable "bastard" type of rock which dominates the Lower Harrodsburg. This lowest unit of the Harrodsburg has been named the Ramp Creek member. The thickness ranges from 17 to 28 feet.

Some uncertainty exists in separating members of the Lower Harrodsburg at places where local crinoidal lenses within the Ramp Creek zone might be confused with the Leesville member and where there is inadequate exposure of the overlying distinctive Guthrie Creek zone. Uncertainty in detecting the base of the Ramp Creek zone (base of the Harrodsburg) is one of the problems for discussion later.

In striking contrast with the Lower Harrodsburg, the upper division is a more regular, more massive, and much more pure limestone. It is usually light gray to blue-gray in color, in some places tinted green. It lacks the prominent yellow color upon weathering. Much of the stone is crystalline and much is quite fossiliferous. Stylolites are common. Chert is far less abundant than in the Lower Harrodsburg. Thin shale partings are not infrequent. Of unusual interest is a zone at the top, commonly four to 10 feet thick, consisting almost entirely of comminuted bryozoans. The thickness of the Upper Harrodsburg ranges from 30 to 50 feet, the usual thickness being about 35 feet.

HORIZONS WHICH MAY BE USED IN DETERMINING GEOLOGIC STRUCTURE

One who is sufficiently familiar with the stratigraphy of the region may, of course, use any horizon which can be detected with certainty as a basis for computing structure. The following is a list of lower Mississippian horizons which may serve with most general satisfaction:

Top of the Harrodsburg limestone
Leesville member of the Harrodsburg
Base of the Harrodsburg (Borden-Harrodsburg contact)
Floyds Knob formation
Top of the Kenwood member of the New Providence
Rockford limestone (at base of the Borden group and top of the New Albany shale)

Locally, where the above listed horizons are uncertain or not exposed, the following may aid materially:

Guthrie Creek member of the Harrodsburg
Mt. Ebel member of the Edwardsville
Dry Creek member of the Edwardsville
Weed Patch member of the Edwardsville
Cutright member of the Edwardsville
Brownstown Hills member of the Edwardsville
Lampkins member of the Carwood

Several of the above-named horizons are not traceable throughout the entire southern Indiana outcrop area. This condition applies particularly to the members of the Borden formations. The Kenwood beds exist only south of east-central Floyd County. Northward, as far as eastern Brown County, there is no clear line of demarcation between the New Providence and Locust Point formations because of the absence of these sandstone beds. The Lampkins sandstone member is restricted to southeastern and part of eastern Monroe County, and southwestern and extreme western Brown County. The Brownstown Hills sandstone member exists in northwestern Washington County, eastern and southeastern Lawrence County, and south-central and western Jackson County. The Cutright sandstone member and the Mt. Ebel sandstone member are found in northern Lawrence County and southeastern, eastern, and northeastern Monroe County. The Weed Patch member is present in eastern Monroe County, and central and western Brown County.

SIGNIFICANT STRATIGRAPHIC PROBLEMS

It has already been emphasized that there are certain perplexing stratigraphic conditions in the lower Mississippian rocks of southern Indiana which must be properly understood before field data for determining geologic structure can be used correctly. The most significant problems arise from *(a)* the complexity of the Floyds Knob limestone, *(b)* the bioherms, and *(c)* the uncertainty of the Borden-Harrodsburg contact in places. No pretense is here made to treat these problems as fully as desired.

Complexity of the Floyds Knob Limestone. Much of the geologic structure in the outcrop area under discussion has been studied by numerous geologists on the basis of the position of the Borden-Harrodsburg contact (base of the Harrodsburg). Considerable limitation arises from the fact that this contact is available only over a restricted area. Wherever this contact is not exposed and only the underlying Borden rocks crop out, geologists have generally been lost. This confusion can be clarified, however, upon finding the Floyds Knob formation (usually a thin limestone) whose position ranges from 40 to 200 feet beneath the base of the Harrodsburg. At other places where the Borden-Harrodsburg contact is absent or not recognizable, but the rocks of the overlying Harrodsburg are present, the Leesville limestone member may serve as a splendid key bed.

At most places within its outcrop area south of northern Lawrence County, as far as Harrison County, Indiana, the Floyds Knob formation can be successfully used as a key formation, since it is generally clearly demarcated from both the underlying Carwood and the overlying Edwardsville units. In this area the Floyds Knob is generally a thin limestone without uniform characteristics. Its properties range between two extremes—an almost pure limestone on the one hand; a highly siliceous, dolomitic, ferruginous limestone that weathers with a deep yellow to chocolate-colored hue, on the other hand. The basal part is conglomeratic at a few places. A sandstone phase (Fordyce Knob sandstone facies), instead of limestone, exists in western Clark County and in limited parts of northeastern Floyd County, southwestern Scott County, and southeastern Washington County. Some difficulty may at first be experienced in locating the Floyds Knob limestone bed because: (*a*) it may be obscured by cover; (*b*) it may be badly weathered; or (*c*) it may have been dissolved away, with only a bed of residual clay left to indicate its original existence.[9]

North of northern Lawrence County through eastern Monroe, western Brown, and southern Morgan counties, the Floyds Knob formation is at many places not separable from the basal Edwardsville rocks above because of lithologic similarities between the two divisions. At some places in this northern region, however, the Floyds Knob formation *is* clearly demarcated and recognizable where it is: (*a*) a hard, brown, crinoidal limestone bed, two to three feet thick; or (*b*) a thin zone of irregular, slightly calcareous rock, brittle, shaly, and arenaceous, usually with lumps of chert, commonly exposed in a partially weathered form with a light buff, yellow, or occasional chocolate-colored hue. In a few places the formation is no more than a thin band of limestone conglomerate resembling that of numerous exposures near the type locality to the south. These facies grade into one another. At those places where the boundary between the Floyds Knob formation and the overlying Edwardsville *can not* be ascertained, one of two situations commonly exists: (*a*) an irregular zone, built up from the base of the Floyds Knob, which is devoid of any definite limestone lenses but consists of slightly calcareous, brittle, sandy shale usually carrying chert lumps and small geodes, con-

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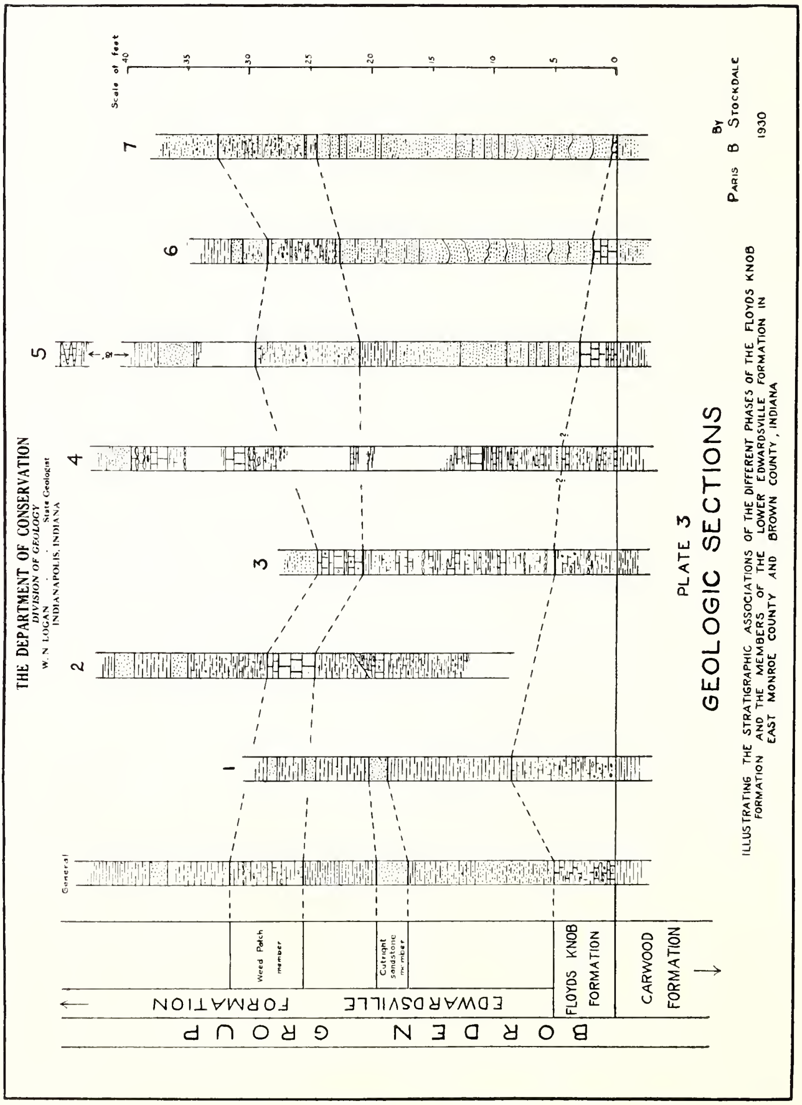
[9] Stockdale, Paris B., Intraformational solution of the Floyds Knob limestone: Proc. Indiana Acad. Sci, for 1929, vol. 39, pp. 213-220, 1930.



THE DEPARTMENT OF CONSERVATION
DIVISION OF GEOLOGY
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PLATE 3

GEOLOGIC SECTIONS

ILLUSTRATING THE STRATIGRAPHIC ASSOCIATIONS OF THE DIFFERENT PHASES OF THE FLOYDS KNOB FORMATION AND THE MEMBERS OF THE LOWER EDWARDSVILLE FORMATION IN EAST MONROE COUNTY AND BROWN COUNTY, INDIANA

By PARIS B STOCKDALE
1930

siderably thicker than the normal Floyds Knob unit (as much as 25 feet or more); or (*b*) a limestone mass extending from the Floyds Knob base up into the overlying Edwardsville formation to a height as great as 70 feet, formed where organisms, particularly crinoids, established themselves in restricted patches for a prolonged time. These organically-made masses are the bioherms. Stratigraphic confusion and misinterpretations of geologic structure have been an outgrowth of erroneous presumptions that various limestone beds and calcareous zones exposed in different sections were at the horizon only of the thin Floyds Knob formation.

At the many places in the northern area where the position of the Floyds Knob formation is in doubt, the situation can be clarified by a study of the associated rocks. (See Plate 3.) The Weed Patch member of the Edwardsville formation lies some 25 feet above the base of the Floyds Knob formation in parts of eastern Monroe County and western and central Brown County. It is at places very similar to some facies of the Floyds Knob, with which it may be readily confused. In its most common weathered occurrence, the Weed Patch member is an irregular sandy zone with a characteristic buff to ocherous color, containing brittle, calcareous, chocolate-colored patches, and usually a few small geodes and nodules of chert. Lithologic variations are noted from place to place. At numerous places both the Weed Patch member and the Floyds Knob limestone are exposed in the same section. At such situations, of course, the two units need not be confused. The sandy rocks lying between the units have at some places, particularly in central Brown County, sufficiently distinctive characteristics to be identifiable. Plate 3 illustrates the stratigraphic associations of various phases of the Floyds Knob formation and the lower members of the overlying Edwardsville formation in eastern Monroe County and western and central Brown County. Locations of the geologic sections shown on this plate are as follows: No. 1, section along Bloomington-Brownstown road, across SE¼ sec. 21, T8N, R1E, eight miles southeast of Bloomington, two miles northeast of old Payne Post Office; bottom of section, three-fourths mile northwest of bridge over Salt Creek; No. 2, section at bluff east side of Stevens Creek, and along sharp tributary ravine, near center sec. 20, T9N, R1E, where road crosses stream, two and three-quarter miles northwest of old Stobo Post Office; No. 3, section near center SE¼ NW¼ sec. 33, T9N, R1E, three-fourths mile northwest of old Stobo Post Office; No. 4, section along old Gosport-Columbus road (abandoned), up steep hill, SE¼ SW¼ sec. 14, T10N, R1E, five miles north, slightly east of old Unionville; No. 5, section along road and in ravine west of road, SE¼ NE¼, near middle of east section line, sec. 9, T9N, R2E, two and one-half miles south of Helmsburg; No. 6, section at Kelly Hill, along State Highway No. 46, NE¼ NW¼ sec. 35, T9N, R2E, two and one-fourth miles southwest of Nashville; No. 7, section along road leading north from Weed Patch Hill, just north of intersection with secondary road which leads west, west-center sec. 32, T9N, R3E, two and one-half miles southeast of Nashville.

Bioherms and Their Significance. Considerable error in interpreting geologic structure in parts of eastern Monroe, western Brown, and southern Morgan counties may arise from misunderstanding the stratigraphic location of limited beds of limestone whose position may be anywhere within the midst of a large, buried calcareous deposit inclosed in the normal clastic strata. Such circumscribed limestone masses are the bioherms referred to earlier. The term "bioherm" has had frequent usage since its proposal by Cumings and Shrock in 1928.[10]

"For several years Indiana workers have been perplexed by a number of disconnected occurrences of heavy crinoidal limestone within the heart of the Borden outcrop belt . . . The 'Knobstone' (Borden) of these investigators was thought to be composed entirely of sandstones and shales. Some suspected the limestone beds to be outliers of the Harrodsburg, made possible by local downfolding or faulting. Others looked upon the masses as odd 'lenses' in the 'Knobstone,' but did not have definite knowledge of the exact stratigraphic positions. The stone of some of these beds has been quarried and crushed for road building. In places the limestone exists in such quantities and with sufficient purity to permit development of sink holes and fair-sized caverns, features extremely unique in the Borden belt.

"The writer has found these limestone masses to be bioherms built up in most cases from the base of the Floyds Knob formation (Cisco Branch facies) and extending varying distances into the basal Edwardsville formation (Allens Creek facies). They may be as much as 70 feet thick and two miles in diameter, but the exact size and shape are usually indeterminable because of insufficient exposures. In ground plan these bioherms are more or less roundish. The bases of the masses are essentially flat and their upper surfaces are no doubt quite uneven. There are lateral offshoots from the main masses furnishing isolated limestone beds at various positions above the horizon of the Floyds Knob in sections exposed near the peripheries of the bioherms. At the margins the limestone grades rather sharply into the inclosing, non-calcareous beds.

"Lower Allens Creek of southeast Monroe County cuts across a typical bioherm of the above described type. Good exposures occur in parts of sections 13 and 24, township 7 north, range 1 west, and sections 18 and 19, township 7 north, range 1 east. The center of the bioherm is near the southeast corner of section 13. Here calcareous deposition went on to the greatest height (about 65 feet) above the base of the Floyds Knob formation. One mile to the east, the bioherm is absent and the stratigraphic interval is a succession of sandstone beds and shaly zones. Geologic sections between these places show progressively more and more limestone to the west toward the center of the bioherm. The exact size of the structure is not determinable because the western part has been cut away at the valley of Salt Creek. Sections exposed along the west side of the valley, a mile or so to the

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[10] Cumings, E. R., and Shrock, R. R., Niagaran coral reefs of Indiana and adjacent states and their stratigraphic relations: Bull. Geol. Soc. America, vol. 39, p. 599, 1928. Cumings, E. R., Lists of species from the New Corydon, Kokomo and Kenneth formations of Indiana, and from reefs in the Mississinewa and Liston Creek formations: Proc. Indiana Acad. Sci., for 1929, vol. 39, p. 207, 1930.

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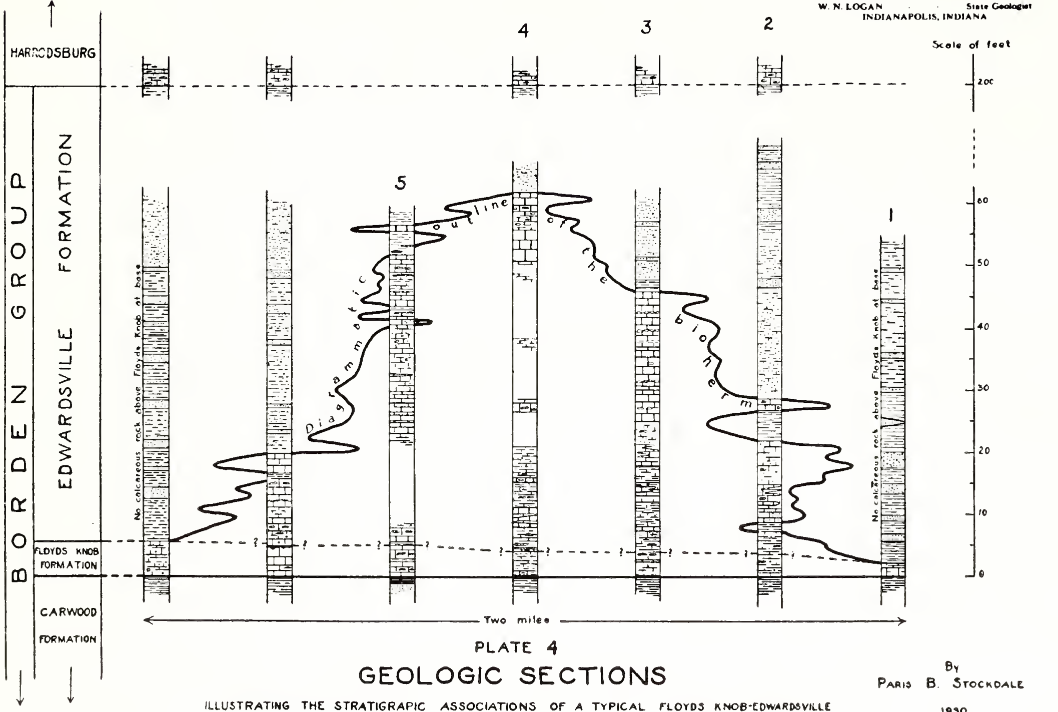

PLATE 4

GEOLOGIC SECTIONS

ILLUSTRATING THE STRATIGRAPIC ASSOCIATIONS OF A TYPICAL FLOYDS KNOB-EDWARDSVILLE BIOHERM AND THE INCLOSING STRATA, AS EXEMPLIFIED BY THE BIOHERM IN THE ALLENS CREEK REGION OF SOUTHEAST MONROE COUNTY, INDIANA

(Note the exaggerated vertical scale)

By
PARIS B. STOCKDALE
1930

west of the place of greatest limestone thickness, give no indications of an excessive thickness of limestone. The diameter of the original bioherm was probably not more than two miles. Aside from outcrops demonstrating the excessive thickness of the limestone, a large sink hole in northeast ¼ southeast ¼ section 13, township 7 north, range 1 west, and a good-sized cave in north-center southwest ¼ section 18, township 7 north, range 1 east, bear testimony of this unusual mass of limestone."[11]

Plate 4 shows several geologic sections illustrating the nature of a typical Floyds Knob-Edwardsville bioherm, as exemplified by the bioherm in the Allens Creek region. Sections 1, 2, 3, and 4 were taken at intervals of about one-fourth to three-tenths of a mile apart. Section number 1 is at the southeast margin of the bioherm, measured along a secondary road which runs northeast at the abandoned Allens Creek Post Office, SE¼ NE¼ sec. 19, T7N, R1E. The thin Floyds Knob formation is present with a thickness of one and one-half feet. There is no limestone above, but instead there is a succession of resistant sandstone beds up to two feet thick, and alternating shale zones. Section number 2 was measured in a sharp ravine in the bluff on the south side of Allens Creek, three-tenths of a mile west of section number 1, SW¼ NE¼ sec. 19, T7N, R1E. In this section variable limestone is present up to 29 feet above the base of the Floyds Knob formation. All but the basal three or four feet of this limestone must be looked upon as belonging to the Edwardsville. Overlying the limestone is normal Edwardsville clastic rock—sandstone, siltstone, and shale. Section number 3, showing 46 feet of calcareous rock above the bottom of the Floyds Knob, was taken from another sharp ravine, one-fourth of a mile northwest of section number 2, at west-center, NE¼ NW¼ sec. 19, T7N, R1E. Again, the upper boundary of the Floyds Knob formation can not be demarcated. Some 40 feet of limestone in this section must belong to the Edwardsville division. Section number 4 is near the heart of the bioherm, about four-tenths of a mile northwest of section 3, at south-center SW¼ SW¼ sec. 18, T7N, R1E. Limestone dominates this section from the base of the Floyds Knob upwards for 62 feet. Nearly 60 feet of the limestone comprises the basal Edwardsville in this section, contrasted with about 40 feet in section number 3, 25 feet in section number 2, and no limestone in section number 1. Section number 5 depicts a readily accessible exposure near the bridge across Salt Creek, one-half of a mile northwest of section number 4.

In the Monroe-Brown-Morgan county area, in southern Indiana, there are at least seven distinct bioherms of the above-described type.

Uncertainty of the Borden-Harrodsburg Contact. The contact between the Borden group and the Harrodsburg limestone is a conformable one. It has at many places served quite adequately in the detection of geologic structure. Too much reliance, however, has been placed by numerous workers on the presumption that the upper Borden rocks (those of the now-named Edwardsville formation) are everywhere clastic in nature in Indiana and are everywhere markedly dissimilar to the overlying calcareous beds of the basal Harrodsburg limestone (those of the Ramp Creek member). Altho this presumption is correct for most of the localities north of southern Floyd County, it is quite erroneous for Harrison County, Indiana, and Jefferson County, Kentucky, to the south. Even in the northern areas where there is generally good lithologic contrast, there are locally some beds of the Ramp Creek member which are so arenaceous and so similar to some of the top Edwardsville beds, which themselves may be slightly calcareous, that difficulty is experienced in finding the exact formational boundary.

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[11] Stockdale, Paris B., Bioherms in the Borden group of Indiana: Bull. Geol. Soc. America, vol. 42, pp. 712-714, 1931.

Greatest confusion has arisen from the Borden-Harrodsburg relationships south of Floyd County. A careful tracing of the rocks southward from the north side of T4S, R5E into Harrison County, Indiana, and Jefferson County, Kentucky, has shown that they become calcareous to lower and lower depths beneath the Harrodsburg. (See Plate 2.) Edwardsville rocks have characteristics identical to those of the Ramp Creek member of the overlying Harrodsburg. Thus the stratigraphic boundary between the two formations is obscured. Because the Borden group includes clastic rocks all the way to the top thruout the better known sections of the Indiana outcrop area, and the group, therefore, has been considered by past workers to be clearly demarcated from the overlying Harrodsburg which is typically a limestone, the Borden division of the southernmost region has generally been thought to terminate with the lowest calcareous, cherty rock, and all limestone beds have been considered as belonging to the Harrodsburg formation.

Thruout practically all of Floyd County the Edwardsville comprises some 50 to 55 feet of sandstone, siltstone, and shale. Beneath it is the thin Floyd Knob limestone; above, 25 to 30 feet of variable impure limestone and calcareous sandstone comprising the Ramp Creek member. Lying upon this is the Leesville limestone member. The 75 to 85-foot interval between the Floyds Knob limestone and the Leesville limestone is one containing both clastic rock (Edwardsville) and calcareous rock (Ramp Creek). But thruout the exposed area south of the middle of T5S, R5E, in Harrison County, Indiana, and Jefferson County, Kentucky, the entire interval is characterized by the variable, impure calcareous rock of the type which to the north is restricted to the Lower Harrodsburg. This stratigraphic condition has led past workers to place the base of the Harrodsburg (Warsaw) at the bottom of the calcareous unit rather than *within* the unit some 50 or more feet above the base. For Jefferson County, Kentucky, Butts correlated all of the above-described zone with the Harrodsburg, after considering the limestone layer which is at the top of his "Holtsclaw sandstone" as marking the "base of the Warsaw."[12] This interpretation, of course, allows an excess of some 50 odd feet to the normal thickness of the Harrodsburg. This excess thickness, in turn, has led some to misinterpret the position of the top of the Harrodsburg as well as the base, and to include the Upper Harrodsburg with the overlying Salem limestone. The two stratigraphic units which serve as keys in clarifying the above-described problem are the Floyds Knob limestone and the Leesville limestone. Both are, as previously stated, recognizable persistent units, on the average about 75 feet apart at their southernmost Indiana occurrences. (See Plate 2.)

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[12] Butts, Charles. See footnote no. 7.

Workers who use the Borden-Harrodsburg contact as a key horizon in detecting geologic structure should not lose sight of the fact that dips computed from this horizon will not be in exact agreement with those calculated from lower horizons because of non-uniformity in thickness of the intervening beds. The Borden group as a whole ranges in thickness in Indiana from 400 feet or more at the south to about 765 feet in central Brown County, 85 miles to the north. The thickness at Bloomington is about 110 feet less than at Nashville, 16 miles (air-line) to the east. The rate of thickness increase between these cities is, therefore, about seven feet per mile. This factor must not be overlooked in comparing geologic structures computed from the horizon of the Borden-Harrodsburg contact with those computed from, let us say, the horizon of the Rockford limestone as determined from well records.

THE COMPLETED OHIO RIVER PROJECT

J. E. SWITZER, Indiana University

Location. The early explorers and trappers who ventured westward across the "Endless Mountains," from any point along a line reaching from the mouth of the Hudson River to the mouth of the Chesapeake Bay, found soon after crossing the last range the headwaters of a stream flowing westward. This westward flowing stream invariably led them either to the Allegheny or Monongahela rivers. These streams span a north-south stretch of some 250 miles from southern New York to central West Virginia, and meet where is now located the city of Pittsburgh, Pennsylvania, to form the Ohio River. On this larger stream born of the union of the two, the trader, trapper, or settler might, with scarcely an interruption, float 981 miles on westward to its junction with the Mississippi. Then from this junction point he might proceed up the Mississippi to the Falls of St. Anthony at Minneapolis. If he preferred he could turn westward up the Missouri which would lead him to the very heart of the Rocky Mountains, or he could float down the Mississippi to its outlet into the great ocean by way of the Gulf of Mexico.

These advantages of position, direction, and connections caused the Ohio River very early to become highly important as a line of communication between the East and the ever increasingly important West.

Characteristics of the Stream. The channel of the Ohio varies in width from about 900 feet in its upper reaches to more than a mile near its mouth. The fall in the first 90 miles, from Pittsburgh to Wheeling, is 11½ inches per mile. From Wheeling to Cincinnati the gradient is only five and one-half inches per mile and from Cincinnati to the mouth four inches per mile, except that the river drops 26 feet in two miles at Louisville in what is known as the "Falls of the Ohio." (Rept. of Chief of Engineers U. S. Army, 1929, p. 1235.)

The river is subject to great fluctuations in level at different seasons of the year. The difference between high water and low water level has reached as much as 30 feet at Pittsburgh, 71 feet at Cincinnati, and 54 feet at Cairo. Before improvements were begun, shoals with a minimum depth of one foot were encountered between Pittsburgh and Cincinnati, and of two feet between Cincinnati and Cairo. Shifting channels, rocks, snags, and sand bars made navigation hazardous. Yet in spite of these handicaps, it is difficult to estimate the value of the Ohio River as a highway for the early traders, trappers, and settlers.

Early Navigation. While thousands of flat boats, rafts, keel boats, and all types of primitive craft floated down the Ohio during the early days of exploration and settlement, the real impetus to river navigation got under way with the advent of the steamboat, the first one of which appeared on the Ohio in 1811. The increased speed and reduced cost of travel, especially up stream, brought about by the

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

steamboat made it the most efficient means of transportation then devised. By 1840 more than 1,200 steamboats were said to ply the waters of the Ohio. Connections with its own tributaries, and with the Mississippi and its tributaries made Ohio River ports accessible to nearly all the centers of dense population at that time west of the Appalachian Mountains. The only effort at improvement of the river to aid in carrying the large amount of traffic was the operation of snag boats and dredges.

Present Project. The first improvement of the Ohio by building permanent locks and dams dates from 1879, when Congress authorized the construction of a dam and lock at Davis Island, 4.7 miles below the junction of the Allegheny and Monongahela Rivers. In 1890, a second dam, now known as No. 6, 29.3 miles below Pittsburgh was authorized to be built. In 1896 Congress ordered four other dams to be constructed between No. 1 and No. 6. Between 1896 and 1909, funds were appropriated for the construction of seven other dams, including No. 26 just below the mouth of the Kanawha River and No. 37 in the western border of Cincinnati. In 1910 there was submitted to Congress a comprehensive plan of improving the Ohio River to provide a minimum depth of nine feet from Pittsburgh to the mouth by the construction of 54 dams with locks.

The original project has been modified by shifting the position and changing the height of some of the dams, so that it has been possible to eliminate dams No. 40 and No. 42. Dams No. 1 and No. 2 have been replaced by a stationary dam at Emsworth, Pa. Nos. 4 and 5 are being replaced by a stationary dam at Dead Man's Island, 13.3 miles below Pittsburgh. The total number of dams, all provided with adequate lockage equipment, in the completed project is 49. Their location, the period of construction, the amount of lift in each lock, and the cost of each are given in the following table.

LOCKS AND DAMS ON THE OHIO RIVER

No. of Dam	Miles below Pittsburgh	Nearest town or city	Lift Feet	Year construction began	Year opened to navigation	Cost
1	4.7	West Bellevue, Pa. (Removed)	3.1	1879	1885	$870,034 01
	6.2	Emsworth, Pa.	10.9	1919	1921	3,082,743 08
2	9.2	Coraopolis, Pa. (Removed)	7.8	1896	1906	976,766 77
3	11.0	Glenosborne, Pa. (To be removed)	7.7	1899	1908	1,144,588 18
	13.3	2 miles below Sewickley (Dead Man's Island)	13.75	1926	1930	3,668,542 23
4	18.6	Legionville, Pa. (To be removed)	7.6	1898	1908	1,071,472 21
5	24.1	Freedom, Pa.	7.5	1898	1907	1,080,132 04
6	29.3	Beaver, Pa.	6.7	1892	1904	1,123,441 80
7	36.5	Midland, Pa.	6.9	1910	1914	1,075,000 00
8	46.4	Newell, W. Va.	6.4	1904	1911	1,167,456 24
9	56.0	New Cumberland, W. Va.	7.4	1910	1914	1,177,100 00
10	66.2	Steubenville, O.	8.4	1912	1915	1,138,000 00
11	76.9	2.3 miles below Wellsburg, W. Va.	7.3	1904	1911	1,162,164 70
12	87.4	Wheeling, W. Va.	8.4	1911	1917	1,166,103 55
13	96.1	McMechen, W. Va.	7.3	1901	1911	1,222,389 11
14	114.0	Woodland, W. Va.	8.3	1911	1917	1,132,934 65
15	129.1	New Martinsville, W. Va.	7.8	1911	1916	1,159,951 82
16	146.5	Bens Run, W. Va.	7.8	1913	1917	1,258,644 43
17	167.5	4 mi. above Marietta, O.	8.2	1913	1918	1,344,915 37
18	179.9	4½ mi. above Parkersburg, W. Va.	6.2	1902	1910	911,405 76
19	192.2	Little Hocking, Ohio	7.7	1908	1916	1,213,259 04
20	202.5	Belleville, W. Va.	7.5	1911	1917	935,926 81
21	214.5	Portland, Ohio	5.6	1915	1919	1,475,836 13
22	220.9	Ravenswood, W. Va.	7.8	1915	1918	1,209,216 84

LOCKS AND DAMS ON THE OHIO RIVER—Continued

No. of Dam	Miles below Pittsburgh	Nearest town or city	Lift Feet	Year construction began	Year opened to navigation	Cost
23	231.4	Millwood, W. Va.	8.1	1917	1921	$1,634,005 08
24	242.5	Graham, W. Va.	7.0	1913	1919	1,112,769 28
25	260.7	5 mi. above mouth of the Kanawha River	9.0	1917	1922	1,708,563 46
26	278.5	Hogsett, W. Va.	7.5	1908	1912	1,267,051 23
27	301.0	4 mi. above Proctorville, Ohio	6.4	1918	1923	2,003,295 90
28	311.6	Huntington, W. Va.	7.1	1911	1915	1,047,667 19
29	319.9	Ashland, Ky.	8.0	1911	1916	1,021,923 37
30	339.4	3 mi. below Greensburg, Kentucky	7.5	1919	1923	1,579,617 80
31	359.3	3 mi. below Portsmouth, Ohio	7.5	1912	1919	1,217,751 24
32	382.6	1 mi. above Rome, Ohio	7.5	1919	1926	2,950,379 98
33	405.1	3 mi. above Marysville, Kentucky	7.0	1915	1921	1,580,948 16
34	434.1	Chilo, Ohio	5.6	1919	1925	3,437,073 70
35	451.0	1 mi. below New Richmond, Ohio	6.4	1913	1919	1,868,849 88
36	460.9	10 mi. above Cincinnati	7.9	1920	1925	3,708,534 91
37	482.2	Fernbank, Ohio	7.8	1905	1911	1,314,178 60
38	503.3	McVille, Kentucky	7.3	1920	1924	2,857,040 24
39	531.7	1 mi. above Markland, Indiana	6.0	1914	1921	2,222,447 98
41	604.0	Louisville, Ky.	37.0	1911	1921	6,886,445 85
43	633.2	3 mi. below West Point, Kentucky	9.0	1914	1921	2,587,331 33
44	663.2	Leavenworth, Indiana	9.0	1920	1926	2,821,222 82
45	703.0	Addison, Kentucky	9.0	1920	1927	3,028,415 00
46	757.3	Owensboro, Kentucky	9.0	1923	1928	2,987,000 00
47	777.7	Newburg, Indiana	9.0	1923	1928	4,412,400 00
48	809.6	6 mi. below Henderson, Kentucky	9.0	1912	1922	2,666,000 00
49	845.0	2½ mi. below Union Town, Kentucky	11.0	1924	1928	3,085,000 00
50	876.8	1 mi. below Weston, Ky.	8.0	1924	1928	3,600,000 00
51	903.1	Golconda, Illinois	8.0	1925	1929	4,500,033 41
52	938.9	1.3 mi. below Brookport, Illinois	12.0	1924	1928	4,314,000 00
53	962.6	10.8 mi. below Joppa, Illinois	13.4	1925	1929	5,304,000 00

Total number of dams constructed, 53.
Number of dams to be used in completed project, 49.
Total cost of construction, $118,743,405.66.
(Ann. Rept. of Chief of Engineers, U. S. Army, 1929, pp. 1239-1241).

Each dam is provided with a navigable pass at least 600 feet wide which can be closed with movable wickets. (Fig. 1.) These wickets are mostly of the Chanoine type and can be raised or laid down as the necessity demands. Each wicket is made of four timbers 12 x 12 inches, the length being determined by the height of the dam. The ones shown in Fig. 2 are 16 feet 11 inches in length and are the type used in Dam No.

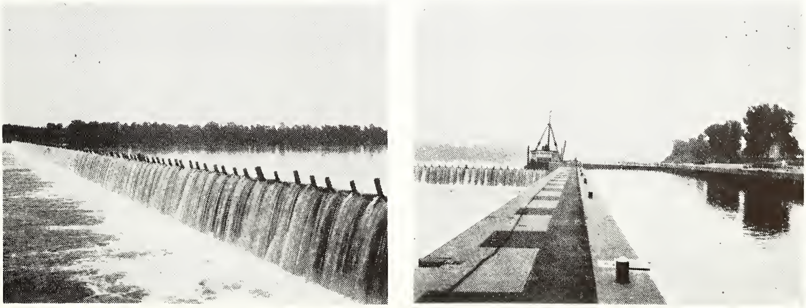

Fig 1. (a) Dam No. 49 located 2½ miles below Union Town, Ky. The "needles" are all in place helping to maintain full pool stage during the drought of 1930.

(b) The lock and a portion of Dam No. 49 and the tender boat. The lock has been filled ready to receive boats from up stream.

37. The four wood beams are bolted to an iron horse which is hinged to the foundation. When raised, the wickets are held in place by an iron prop which weighs nearly a half ton, the weight of the entire wicket is about three tons. By a system of grooves and notches for the prop to slide in, the wickets may be raised or lowered very easily by the tender boat that forms part of the equipment of each dam. To lay the wickets down, it is only necessary to pull back the top of the wicket until the "prop" slides out of the supporting notch and into a groove which guides the end of the prop around the notch as the prop slides forward and lets the wicket lay flat on the foundation. To raise the dam, each wicket is caught on the under side and pulled up until the prop drops into its notch, then the pressure of the water forces the wicket into place and holds it there. A wicket may be laid down in two minutes, and a whole dam may be raised in five or six hours.

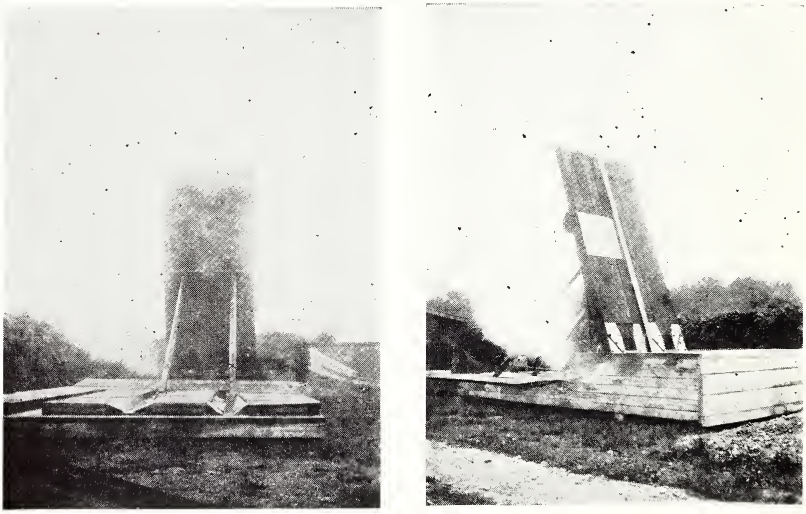

Fig. 2. (a) Down stream view of two Chanoine Wickets as they would appear in Dam No. 37. Shows the "props," their attachment and that of the timbers to the "horses" and the grooves that guide the "props" when the wickets are being raised or lowered.

(b) Up stream view of the same wickets. The "needle" fills the four-inch space between the wickets.

In operation of the dams to maintain a nine foot depth, the water is never allowed to get much higher than the top of the wickets. The depth of the water in the pool is regulated in most of the dams by outlet valves called "Bear Traps." These may be opened to let more water pass below the dam if the level of the pool tends to rise to heights that would cause too great pressure on the wickets. If the open "Bear Traps" fail to lower the water sufficiently, some of the wickets are laid down to let yet more water pass. A space of four inches is left between wickets. If the water becomes unusually low, as during the drouth of 1930, these spaces are closed by 4 x 4 inch timbers. In extreme need, straw or grass may be packed in back of the needles to still further aid in maintaining full pool depth of water. That the government engineers have efficiently provided for the maintainance of a nine foot depth in minimum low water conditions was well demonstrated during the unprecedented drought of 1929-1931. In spite of the lack of precipitation, all pools were kept at full pool stage throughout the summer of 1930, and no hindrance to navigation throughout the 981 miles of the river could be attributed to low water.

When flood stage approaches or ice flows are to be encountered, all the wickets are laid down and all boats use the open channel. When the wickets are raised all boats must pass through the locks in going either up or down stream. The locks with two exceptions are 110 feet wide and 600 feet long and, for the most part have a lift of 6 to 9 feet.

Dam No. 41 at Louisville differs from the others in that the fall there is greater and water power is developed by the Louisville Hydroelectric Power Co. The entrance to the locks instead of being directly from the river is through a canal two miles long. The construction of a power plant by the Louisville Hydro-electric Power Co. began in May, 1926, and by December, 1927, all eight turbines were in operation. During the fiscal year 1929, the amount of electricity produced was 218,079,810 kilowatt hours. The company built their own plant and hold a 50 year lease of water power rights for which they pay the government $95,000 annually. This dam cost the government, as shown in the table, page 7, $6,886,000. The government receives, therefore, in payment for water rights, approximately one-third the equivalent of 4 per cent interest on its investment in this one dam and locks.

Distribution of Tonnage Shipped on the Ohio River in 1930. A glance at the chart, Fig. 3, shows that most of the traffic hauled on the Ohio River is carried over two main sections. One extends from the source of the Ohio at the junction of the Allegheny and Monongahela rivers to a point about 70 miles down the river. The other section is from the mouth of the Kanawha River to Cincinnati, a distance of about 225 miles. On the remainder of the river there is relatively little traffic, although here and there the amount perceptibly is increased by local supplies of, or demand for, some bulky commodity.

A closer scrutiny and analysis of the statistics shown by the chart discloses, among other things, the following facts:

1. The maximum tonnage on any part of the river is found in the first few miles below its source in the heart of the city of Pittsburgh. Here the tonnage reaches the grand total of 10,300,000 tons.
2. At a distance of some 16 miles down stream the tonnage decreases to about 5,500,000 tons, and at 35 miles down stream to 3,100,000 tons.
3. Between a point 70 miles from the junction of the Allegheny and Monongahela rivers and the mouth of the Kanawha River, a distance of approximately 180 miles, only about 750,000 tons are shipped.
4. Between the mouth of the Kanawha and Huntington, West Virginia, the tonnage increases to 3,600,000, but 50 miles further down stream it drops to about 3,000,000 tons and remains about this amount to Cincinnati.

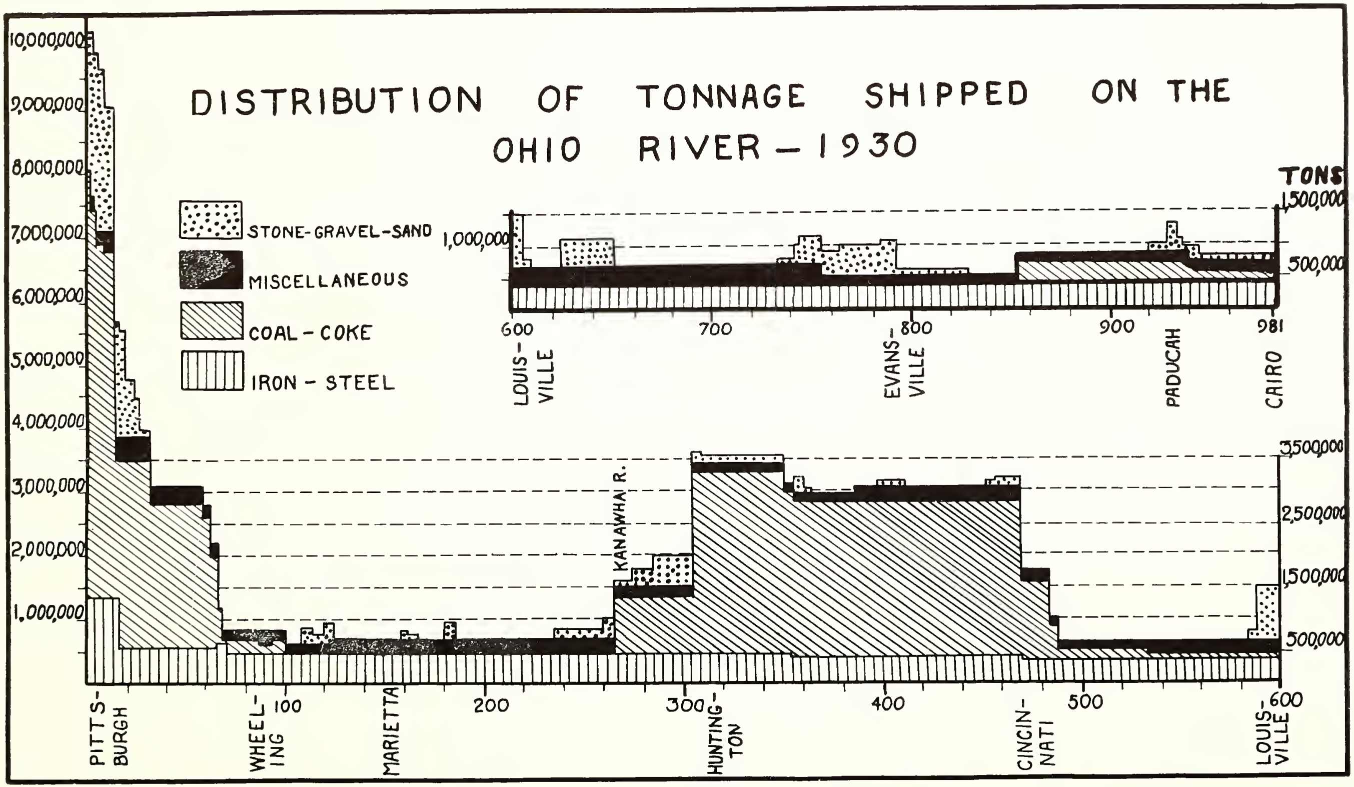

Fig. 3. A graphic representation of the distribution of the tonnage shipped on the Ohio River during the year 1930. The numbers at the bottom give the distances from the junction of the Monongahela and Allegheny rivers, those at the side represent tons shipped. (Data from the Ohio Valley Improvement Association.)

5. Down stream from the western suburbs of Cincinnati the tonnage drops to between 700,000 and 800,000 tons and, except for local increases in sand and gravel shipments, retains about this amount the remaining nearly 500 miles of the river's course.

6. The chief items of traffic are coal and coke, iron and steel, stone, sand and gravel. Iron and steel products are the only ones that have continuous shipments the full length of the river, some 250,000 tons of which reach Cairo, destined for Mississippi River ports.

By way of summary of traffic it may be noted that of the 22,337,000 tons of freight transported on the river during the year, about one half is confined to the first 16 miles of the river, which is in the city of Pittsburgh and its immediately adjoining suburbs; that about 675 miles of the total 981 miles of improved river carried an average of only about 750,000 tons during the year 1930.

Some reasons for the distribution of traffic. In the first place, the Allegheny and Monongahela rivers, likewise the Ohio, have cut their valleys deep, with steeply sloping valley walls. Pittsburgh, located at their junction point, is in a region of considerable relief. The only portions of the city having a topography suitable for factories handling heavy materials are the rather narrow strips of flat lands in the valley bottoms. These flat lands are not only favorably located in regard to traffic carried by the river, but occupy the only areas in which railways may be easily built. Hence river borne material may be readily supplemented by traffic by railways.

The Monongahela River passes through the highly productive coal field of southern Pennsylvania and West Virginia, an area of high grade coking coal, excedingly important to the steel industry of the Pittsburgh region. The river has cut through seams of the coal, and many mines "drift in" from the sides of the valley hence find it very convenient to bring the coal out to the valley and dump it in barges to be floated down stream. More than 20,000,000 tons are shipped annually in this way. Many coking plants are located near the mines and use the same method of transportation. Thus it is that a considerable part of the coal and coke tonnage on the Ohio River in the immediate vicinity of Pittsburgh is composed of Monongahela River coal and coke tonnage which, as it passes beyond the junction point of the rivers, becomes tonnage on the Ohio River. This tonnage of coal and coke amounts to about 6,500,000 for the first two miles, decreases to 5,500,000 tons at the down stream side of the city of Pittsburgh, to less than 3,000,000 tons 17 miles down stream, and to 150,000 tons at Steubenville, 70 miles below the junction point.

The shipment of approximately 1,300,000 tons of iron and steel in the first 17 miles of the river suggests the importance of the location of the steel mills near the river and of the use of the river in transporting materials between the mills. The chart shows that nearly half the iron and steel shipped by the river route is destined for down stream markets, about 100,000 tons for the Steubenville area, another 100,000 tons for Cincinnati.

Almost no coal is shipped on the Ohio between Wheeling and the mouth of the Kanawha River. The Kanawha contributes nearly a million tons of coal consigned to Ohio River ports. The far southward bend of the Ohio brings it to the coal fields of the Huntington district which supplies an additional two million tons, consigned to the Cincinnati area. A small amount of this coal is carried as far as Louisville, Kentucky.

In the last 100 miles of the river the producing coal mines of western Kentucky and southern Illinois furnish another source of supply of coal for shipment. This area ships some 250,000 tons between Caseyville and Paducah, and 100,000 tons from Paducah to the mouth.

Stone, sand and gravel become conspicuous items in the tonnage only for local areas, notably in the vicinities of cities or where the conditions of the river channel require considerable dredging.

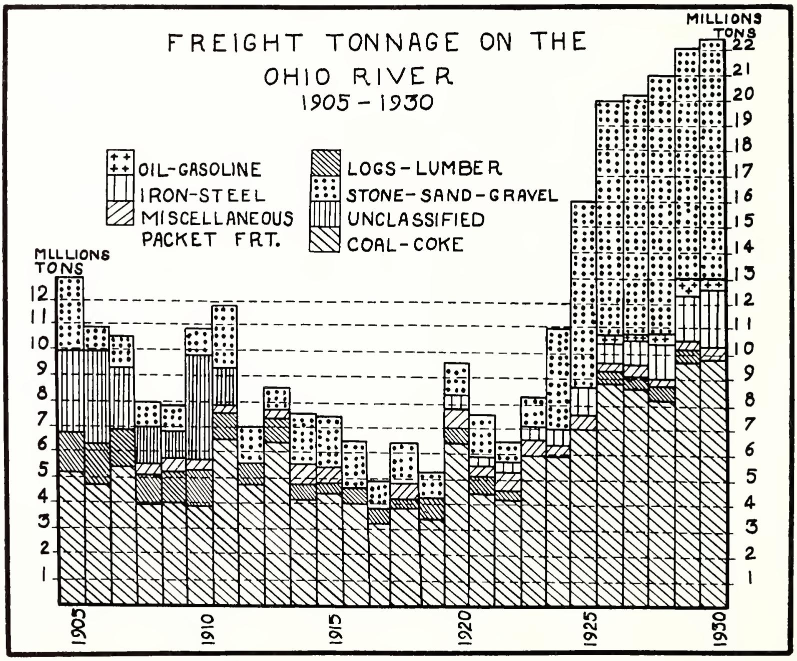

Fig. 4. Tonnage of groups of commodities shipped on the Ohio River during the years 1905-1930. (Adapted from chart furnished by the Ohio Valley Improvement Association.)

Miscellaneous freight is composed of cement, logs, lumber, oil and gasoline, and packet freight. Oil and gasoline form about two-thirds of the miscellaneous freight between Louisville and Owensboro (mile 755) and constitutes part of the tonnage nearly the whole length of the river.

Traffic on the Ohio River from 1905 to 1930. Figure 4 shows the total freight tonnage on the Ohio River during the past 26 years. At a glance one is impressed with the great increase in tonnage shipped due, apparently, to the improvements that have been made. The data of the chart must be examined closely to appreciate the full import of the facts shown. It is shown that the marked increase in tonnage shipped dates from 1925, and that the increase has been largely in stone, sand and gravel, which since 1924 have constituted about 40 per cent of the total tonnage. Methods of compiling statistics of sand and gravel shipments were changed in 1925 and since then sand and gravel dredged from the channel are rated as "tonnage" even though it may not be shipped out of the pool in which it is dredged. Since the average haul of sand and gravel is less than 15 miles, in only a few cases could more than one lock be used in the transportation of any consignment. It may be noted in Fig. 3 that sand and gravel shipments are confined to very local areas, approximately two-thirds of which are in the first 30 miles of the river's course. It would seem that where a local demand exists, gravel would be dredged regardless of any general plan of navigation improvement. Aid to shipment of sand and gravel then, can hardly be urged as an important reason for the construction of a large series of dams and locks to make the river navigable from its head to its mouth.

The benefits of improvement of the river should be expressed in terms of increase of tonnage of commodities that actively enter into commerce, which tonnage would not be transported on the river if the improvements had not been made. Omitting from the picture for the present the items of stone, sand and gravel, let us see how the tonnage of the other items compare during the different years.

The 26 years of record may be divided into three periods of variation in shipments, i. e., the years of 1905-1911 inclusive, in which the tonnage shipped ranged fairly high; the years 1912-1923 in which the tonnage shipped was relatively small; and the last seven years, 1924-1930, in which there was a steady increase in shipments. Omitting sand, gravel and stone, the chart shows that the freight shipped in 1905, 1906, 1907, 1910 and 1911, was not exceeded until 1926, and but slightly until 1929 and 1930. The average annual tonnage shipped during the first period (1905-1911) was 8,750,000 tons while that for the last period (1924-1930) was 10,600,000 tons or 1,850,000 tons greater. The very small tonnage of the middle period is no doubt partially a reflection of the conditions during the World War when speed was a very important item in transportation. The increase in tonnage of coal and coke, and of iron and steel, and the use of the river in transporting oil and gasoline during the last period should be noted.

In 1905 only Dam No. 1, just below the city limits of Pittsburgh, and No. 6 (29.3 miles down stream), had been completed. By 1911 there had been completed and opened for navigation the first six dams with their locks, also Nos. 8, 11, 13, 18, and 37. Between 1911 and 1923, twenty-six additional dams and locks had been completed and put into use. Yet in spite of this additional improvement of the river for carrying trade, the tonnage was appreciably less than during the 1905-1911 period. By 1928 all locks and dams were practically completed and the minimum depth of 9 feet was maintained throughout the river's length. The freight tonnage during the last two years of the record was (besides stone, sand and gravel) 13,000,000, tons, only about 3,000,000 tons greater than that of 1905 and 1906, when only two dams and locks were in operation.

Cost of the project and of transportation. The estimated cost of the construction of all the dams, locks, and their associated works (made by the Chief of Engineers) is $118,743,405.66 (Ann. Rept. Chief of Engineers, U. S. Army, 1929, p. 1241). This does not include the cost of improvement of the channel by dredging, the average annual cost of which has been $110,000 for a century.

Neither do these estimates include the salaries of the government engineers who have contributed much of their time in making surveys and supervising the work of construction. Their salaries are paid out of funds appropriated for and charged to maintenance of the U. S. Army. To these items should be added interest on the sums expended from the time of the expenditure to date.

And estimated annual cost of maintenance of the completed project is $2,000,000 (Ann. Rept. Chief of Eng., U. S. Army, 1929, p. 1237).

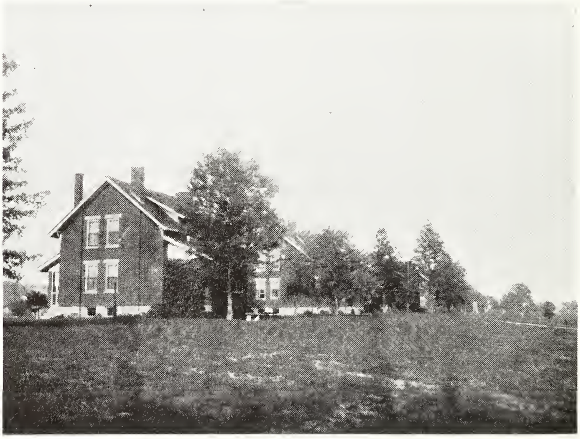

Fig. 5. Homes of the employees at Dam No. 37. These beautiful houses of brick are built on the grass covered levee facing the river, but are high enough to be out of reach of flood waters. The dam and lock are just beyond their front yard.

At most of the dams nine men are employed. They are furnished homes in which to live, some of the best types of which are shown in Fig. 5.

The total *annual cost* to the government of maintaining a minimum depth of nine feet for the length of the river is made up of at least the following items:

1. Interest at four per cent on at least $118,000,000 which is $4,720,000.
2. Cost of maintenance $2,000,000.
3. Salaries of army engineers who are devoting their time to the supervision of the operation of locks, dredges, and dams.
4. Interest on sums spent in "maintenance" since operations of the locks began.

Since these sums are all paid out of the treasury, it matters not whether bonds bearing interest have actually been sold for this especial use, for the sums invested in this and all other similar projects could otherwise have been turned to the reduction of the bonded indebtedness of the government. Directly or indirectly, it comes from the purses of the people, and since no tolls are charged for the use of the locks, there is no direct way in which it can possibly *ever* be returned to the treasury. The making of any appropriations for the retirement of the sums invested, or for paying interest on those sums, must come from the same source as the original sums. They can be paid only by "taking money out of one pocket and putting it into another," a mere matter of bookkeeping, not of reducing the debt, so far as treasury funds are concerned. Financial returns on the investment then must be found on reduced freight rates on an adequate amount of tonnage for an adequate length of haul to repay to the people at least a reasonable interest on the money invested.

It is clear that approximately two-thirds of the river is little used. In the little used portions there have been constructed 28 dams and locks at a cost of over $70,000,000. Interest on this sum at four per cent (the war debt rate) is $2,800,000. The cost of maintenance of these dams and locks, based on the engineer's estimate of the cost of maintenance of the whole project, is at least $1,200,000 annually. Thus a conservative estimate of the annual cost of this portion of the project, not providing for liquidation of the original sum, is at least $4,000,000. The tonnage hauled over this portion, as already noted, averages approximately 750,000 tons. The cost to the people of the United States, therefore, averages about five dollars for each ton shipped over these portions of the improved river. This sum is expended to maintain a highway free of charge, to companies operating boats and barges, that they may haul freight somewhat cheaper than it can be hauled by rail, trolley or bus, on the theory that this competition will keep down all freight rates. Is this an economic way of securing cheap transportation?

The tonnage hauled over the first 70 miles of the river's course and over that portion between the mouth of the Kanawha and Cincinnati may be considered adequate to warrant the improvement of those areas. It yet remains to be demonstrated that the expenditure of the vast sum for the improvement of the whole river has been an economic investment.

NOTES ON THE GLACIAL BOUNDARY IN SOUTHERN INDIANA

W. D. THORNBURY, Indiana University

The purpose of this paper is to describe briefly the occurrence of some glacial and glacio-fluviatile deposits which were discovered by the writer during the summer of 1931. So far as the writer is aware these deposits have not yet been described, and since their discovery will make necessary some modifications of the Illinoian glacial boundary in southeastern Indiana, it was thought wise to report their discovery.

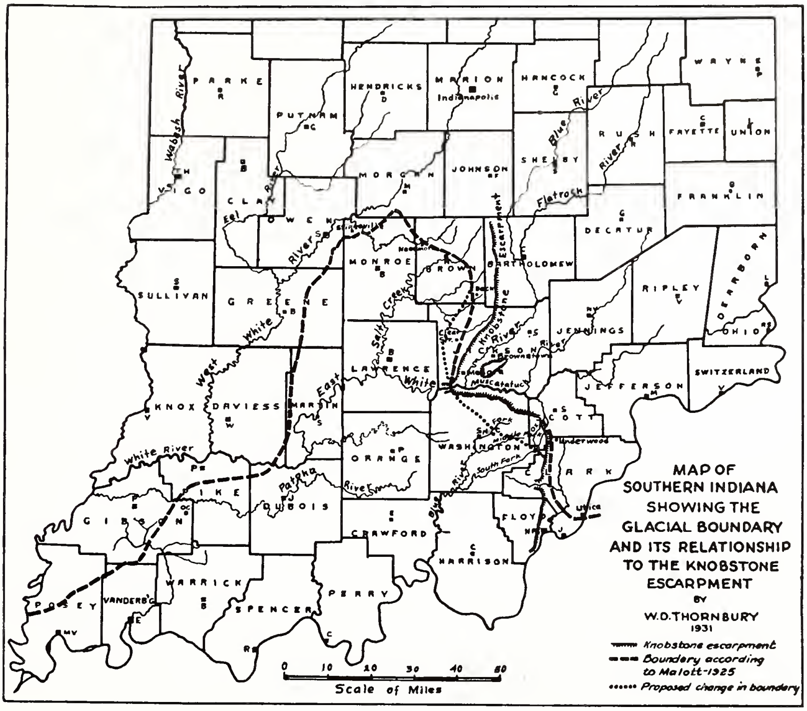

FIGURE 1

Fig. 1. Glacial boundary in Indiana showing its relationship to Knobstone Escarpment.

During the latter part of the summer of 1931, the writer was engaged in some field work dealing with the physiographic history of the Knobstone escarpment, or the so-called "Knobs" of western Bartholomew, western Jackson, eastern Washington, western Scott, western Clark, and eastern Floyd counties. One problem which arose in connection with the study of the escarpment was its relationship to the glacial boundary

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in southern Indiana. It became necessary to determine to just what extent the escarpment had acted as a barrier to the southwestward advance of the ice and how far beyond the escarpment the ice had extended.

Previous work by Leverett, Malott, and others[1] had fixed fairly definitely the Illinoian boundary in Indiana, especially in the southwestern part of the state. No glacial drift had been discovered west of the Knobstone escarpment anywhere south of the Muscatatuck River and the East Fork of White River. Glacial drift had been reported by Malott in 1925, up the Millport Knob road (State Highway 35) just southwest of where it crosses the Muscatatuck River, but this drift was at an elevation between 700-800 feet and did not extend up to the top of the escarpment. At no place south of the Muscatatuck River had glacial drift been found above an altitude of 800 feet, whereas the escarpment attains altitudes between 900-1000 feet at several points between the Muscatatuck and Ohio rivers.

The southernmost point where glacial drift had been found west of the escarpment previous to this work is along U. S. Highway 50, about three and one-half miles northwest of Medora, near the center of section 29 T3N, R3E. About ten feet of till are exposed at this place, the upper part of which is deeply weathered. It had generally been believed that the ice had surrounded the Brownstown Hills but had not extended over their tops. It appears likely now, in view of the fact that glacial drift has been found at an altitude of 930 feet from 12 to 15 miles south of the Brownstown Hills and west of the escarpment, that these hills may have been covered entirely by ice. The highest hills attain altitudes of approximately 945 feet. The writer has not made a careful search of the Brownstown Hills for glacial drift. Such a search may not reveal any drift, as the post-glacial erosion may have removed all traces of drift from their tops.

The first suggestion that glacial materials might be found west of the escarpment farther south than had hitherto been reported came with the discovery of a two-foot granite boulder in the upper part of the valley of Delaney's Creek in section 24, T3N, R4E. In addition to this large boulder there is present a considerable number of smaller glacial boulders and pebbles along the side of the valley and up the tributary valleys. It was supposed, however, that this material was probably deposited by a tongue of ice extending up this valley from the lowland to the east or rafted in on floating ice in a lake which appears to have occupied the valley of Delaney's Creek during a part at least of Wisconsin glacial times. This lake was formed by the ponding of the waters of the Muscatatuck and its tributaries by the valley train developed along White River.

Several days later, however, while driving along State Road 56, between Scottsburg and Salem, glacial material was discovered in a road cut about one-half mile west of the escarpment near the south-central part of section 32, T3N, R5E. The altitude as determined by an aneroid barometer was 930 feet. Careful examination of this material revealed the presence of numerous white quartz pebbles and boulders of quartzite, granite, and greenstone. This discovery led to a more detailed search for glacial material west of the escarpment. The time available did not permit a thorough study of the region, but the results thus far seem important enough to justify calling attention to them in this brief paper.

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[1] For an excellent review of the work done in Indiana upon determination of the position of the glacial boundary the reader is referred to a paper by C. A. Malott, The Glacial Boundary in Indiana, Proc. Ind. Acad. Sci. 35: 93-107, 1925.

No striking changes are as yet indicated as necessary in Jackson County, but glacial drift was found at three places slightly farther west than hitherto reported. Drift has been discovered in the following localities:

1. East-central part of section 24, T6N, R2E, about one and one-half miles southeast of Norman station.
2. East-central edge of section 36, T6N, R2E, and on opposite side of road in section 31, T6N, R3E, about two and one-half miles south of Clear Spring (Old Mooney postoffice).
3. Near center of section 19, T5N, R3E.

These discoveries will move the boundary somewhat farther west, but will not make necessary as much change as will be necessary in Washington County. Glacial drift had already been found west of the escarpment in Jackson County, about one-half mile southeast of Clear Spring.

Previously the glacial boundary had been drawn in Washington County at the foot of the Knobstone escarpment. Glacial drift or glacial boulders can be said to be definitely present at the following localities in Washington County, west of the escarpment:

1. One-half mile northeast of the West Point M.E. Church in the SW¼ of section 29, T3N, R5E.
2. Near east-central part of section 35, T3N, R5E.
3. Near middle of south section line of section 32, T3N, R5E.
4. In the NE¼ of section 4, T2N, R5E, about one mile northeast of New Philadelphia.
5. Near the central part of section 12, T2N, R4E, about one-half mile northeast of Canton, along State Highway 56.
6. In the north-central part of section 19, T2N, R5E, one mile northeast of Harristown.
7. In the west-central part of section 19, T2N, R6E.
8. In the SW¼ of section 30, T2N, R6E, along Henryville-Salem road, about one-fourth mile east of Bunker Hill Church.
9. In the east-central part of section 33 and west-central part of section 34, T2N, R6E, about one mile east of the Liberty Church in a cut in a road leading north from the Henryville-Salem road There is perhaps as much as 60 feet of drift present here in the form of what is apparently a terminal moraine.
10. In the north-central part of section 4, T1N, R6E, upon the farm of Rev. W. D. Bartle.

There are doubtless several other places in eastern Washington County where glacial drift may be found, but these are sufficient to prove conclusively that the ice did pass over the escarpment, and reach as much as five or six miles beyond it. Further work will be necessary in order to fix the boundary exactly.

It is interesting to note in this connection the presence of a rather well-developed valley train in the upper part of the Pekin (South) Fork of Blue River. Numerous glacial pebbles and boulders are present beneath and in the alluvial terraces of the broad valley floor. It appears that this fork of Blue River acted for a time as the outlet for the melt waters from the ice front which lay a short distance west of the rim of the Knobstone escarpment near the headwaters of the Blue River system. The terraces along the valley of Blue River appear to be composed largely of glacio-fluviatile material and represent remnants of this old valley train. Whether or not outwash material is present in the headwater portions of the other two forks of Blue River, the writer is unable to state definitely, but it seems very likely that a careful search will reveal evidence of valley trains along these two streams; as glacial material is unquestionably present near their headwaters. If such be the case, Blue River at one time must have carried a considerable volume of glacial waters. It may well be designated an Illinoian glacial sluiceway.

The fact that the headward portion of the Pekin Fork of Blue River is a wide, flat valley a mile or more in width and occupied by a stream much smaller than one would expect in such a valley, led to a search for an explanation of this fact. The explanation seems to lie in two things, first, the above-mentioned fact that during a part of Illinoian times this valley acted as a route through which glacial waters were discharged from the Illionian ice front, and secondly, in the fact that subsequent to the withdrawal of the ice a portion of the upper drainage of this fork of Blue River has been beheaded by the northeasterly-flowing Big and Little Ox Creeks. This piracy has been possible because of the much steeper gradient of the two Ox creeks down the front of the Knobstone escarpment. Just how much of the Blue River drainage has been diverted into the Ox creeks can not be said until the region has been mapped, but it seems probable that several square miles of drainage have been lost to Blue River. This case of piracy is particularly interesting in view of the fact that Dr. C. A. Malott has previously described[1] a notable case of stream piracy affecting a tributary of this same fork of Blue River. In this case, about 35 square miles of Blue River drainage has been diverted into the drainage of Silver Creek, due to conditions similar to those described above. Thus we have presented the very unusual occurrence of two cases of stream piracy affecting parts of the same stream system. This is the first case of this which has come to the writer's attention.

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[1] C. A. Malott, Handbook of Indiana Geology, pp. 180-186, 1922.

A LIST OF CALOOSAHATCHIE PLIOCENE SPECIES

H. I. Tucker and D. Wilson, DePauw University

In 1928 the authors began collecting material and studying the Caloosahatchie formation in the field. Since that time considerable work has been done under the direction of Professor G. D. Harris at Cornell University.

The writers are indebted to Professor Harris for permission to publish and for the use of the research facilities of the Paleontology Laboratory. They are also indebted to Dr. Floyd Hodson for the privilege of studying specimens in his South American Tertiary collections.

In this list, species from Moore Haven, Fla., are marked H; from Ft. Denaud, Fla., D; from Buckingham, Fla., B; from Prairie Creek, Fla., P; those from Okeechobee City, Fla., O; from Port Mayaca, Fla., M; from Acline, Fla., A.

Glycymeris americana Defrance, P, A.
Glycymeris pectinata Gmelin, H, D, A.
Arca wagneriana Dall, H, D.
Arca aquila Heilprin, H, D.
Arca occidentalis Philippi, M.
Arca caloosahatcheensis Sheldon, P, M.
Arca millifila Dall, P.
Arca millifila Dall var., M.
Arca reticulata Gmelin, D.
Arca adamsi Smith, H, D, P, M.
Arca taeniata Dall, H, D, P.
Arca limula Conrad, H, D, P.
Arca scalarina Heilprin, H, D, A.
Arca lienosa Say, H, D, P, A.
Arca campyla Dall, H, D.
Arca rustica T. & H., H, D, P.
Arca æqualitas n. sp., M.
Arca acompsa media n. subsp., A.
Arca (Barbatia) aclinensis n. sp., A.
Arca chiriquensis Gabb, A.
Ostrea haitensis Sowerby, A.
Ostera haitensis Sowerby, A.
Ostera disparalis fredeai F. Hodson, A.
Pecten caloosaensis Dall, D.
Pecten exasperatus Sowerby, H, D, P, M.
Pecten gibbus Linné, M.
Pecten eboreus Conrad, H, D, P.
Pecten sp., B.
Pecten eboreus solarioides Heilprin, H, D P.
Pecten pittieri floridensis n. subsp., B.
Pecten interlineatus Gabb, B.
Amusium mortoni Ravenel, H, D, P.
Spondylus rotundatus Heilprin, H, D, P.
Anomia simplex d'Orbigny, H, D, P.
Periploma angulifera Philippi, P.
Crassatellites gibbesii T. & H., P, A.
Chama Willcoxi Dall, H, D, P, A.
Chama crassa Heilprin, H, D.
Echinochama arcinella Linné, H, D, P, M, A.
Codakia orbicularis Linné, H, D, P, M.
Lucina chrysostoma Philippi, H, D, P, M.
Phacoides pensylvanicus Linné, H, D, P, M, A.
Phacoides amabilis Dall, H.
Phacoides anodonta Say, H, D, M, A.
Phacoides radians Conrad, H, P, M.
Miltha caloosaensis Dall, H, D, P, M, A.
Miltha disciformis Heilprin, H, D, P, A.
Divaricella compsa Dall, H, P, M.
Diplodonta acclinis Conrad, D, A.
Cardium emmonsi Dall, H, D, P.
Cardium isocardia Conrad, M.
Cardium oedalium Dall, H, D, P, A.
Cardium aclinensis, n. sp., A.
Cardium dalli Heilprin, H, D.
Cardium robustum Solander, H, D, P, M, A.
Cardium willcoxi Dall, H, D, P.
Cardium serratum Linné, H, D, P, M.
Dosinia elegans Conrad, H, D, P, M, A.
Macrocalista nimbosa Solander, H, P, M, A.
Macrocalista maculata Linné, H, D, P, M.
Cytherea willcoxi Dall, H.
Cytherea rugatina Heilprin, H, D.
Chione cancellata Linné, H, D, P, M, A.
Chione cribraria Conrad, P, M, A.
Chione latilirata Conrad, P, M, A.
Chione grus Holmes, H, D, P.
Venus tridacnoides Lamarck, P.

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Venus campechiensis Gmelin, H, D, P, M, A.
Tellidora cristata Recluz, H, P, M, A.
Psammosolen Cumingianus Dunker, H, D.
Mulinia sapotilla Dall, D.
Rangia cuneata Gray, D.
Labiosa lineata Say, H.
Labiosa canaliculata Say, H, D, P, M.
Physa meigsii Dall, D, P, A.
Conus adversarius Conrad, H, D, P, A.
Conus proteus Hwass, A.
Conus pealli Green, H, D, P.
Conus floridanus Gabb, H, D, P, A.
Conus daucus Linné, H, D, P.
Conus delessertianus Recluz, H, D, P, M.
Conus centurio Born, D.
Cancellaria conradiana Dall, H, D, P, A.
Cancellaria barretti Guppy, H, D, A, O.
Cancellaria tabulata Gardner & Aldrich, A.
Cancellaria sericea Dall, H, D.
Cancellaria tenera Philippi, H.
Cancellaria caloosahatchiensis, n. sp., D.
Cancellaria venusta T. & H., H, P, D.
Perplicaria perplexa Dall, H, D.
Maculopeplem floridanum Heilprin, H, D, P.
Mitra lineolata Heilprin, H, D, P.
Mitra holmesii Dall, H, D.
Mitra willcoxi Dall, H.
Vasum horridum Heilprin, H, D, P, A.
Fasciolaria tulipa Linné, H, D, P.
Fasciolaria apicina Dall, H, D, P, M, A.
Fasciolaria monocingulata Dall, D.
Fasciolaria gigantea Kiener, H, D, P, A.
Fasciolaria sparrowi Emmons, A.
Fasciolaria okeechobensis, n. sp., M.
Liochlamys bulbosa Heilprin, H, D.
Latirus tessellatus Dall, D.
Latirus hypsipethus Dall, D.
Busycon pyrum Dillwyn, H, D, P, A.
Busycon planulatum Dall, H.
Busycon maximum Dall, H, A.
Busycon maximum var. rapum Heilprin, H, D.
Busycon perversum Linné, H, D, P, M, A.
Busycon echinatum Dall, H, P, A.
Melongena subcoronata Heilprin, H, D, P, M.
Melongena consors Sowerby, O.
Solenosteira mengeana Dall, H, D, P, A.
Solenosteira mengeana caloosana, n, subsp., P.
Solenosteira vaughani aclinensis, n. subsp., A.
Fusinus caloosaensis Heilprin, H, D, P, A.
Tritonidea auritula Link, P.
Tritonidea cancellaria Conrad, P, O.
Engina turbinella Kiener, D.
Murex messorius Sowerby, H, D, P.
Murex rufus Lamarck, H, D, P, A.
Murex pomum Gmelin, H, D, P, A.
Murex (Pteropurpura) textilis Gabb, H, D, A.
Murex (Pterorhytis) fluviana Dall, D.
Eupleura caudata Say, H, D, P.
Eupleura caudata var. sulcidentata Dall, H, D.
Ocinebra cellulosa Conrad, D.
Aspella engonata Dall, H, P.
Typhis floridanus Dall, H, A.
Coralliophila lepidota Dall, H, D, P, A.
Niso willcoxiana Dall, H, D, P.
Colubraria floridensis, n. sp., P.
Cassis floridensis, n. sp., A.
Pyrula papyratia Say, H, D, M.
Cypraea problematica Heilprin, H, D, P.
Cypraea carolinensis floridana Mansfield, A.
Trivia suffusa Gray, H, D, P.
Trivia pediculus Linné, H, D.
Trivia globosa Gray, H, D, P.
Trivia incerta, n. sp., H.
Cyphoma gibbosa Linnaeus, M.
Erato cf. maugeriæ Gray, H, D, P.
Strombus pugilis Linné, M.
Strombus pugilis var. alatus Gmelin, H, P, M, A.
Strombus leidyi Heilprin, H, D, P,
Potamides scalatus Heilprin, H, D, P, M.
Modulus floridanus Conrad, H, M.
Modulus modulus Linné, H, D, P, M, A.
Turitella subannulata Heilprin, H, D, P, O, A.
Turitella peraltenuata Heilprin, H, D, P.
Turitella apicalis Heilprin, H, D, P, A.
Ampullaria hopetonensis Lea, M.
Ampullaria depressa Say, M.
Architectonica granulatum Lamarck, A.
Natica canrena Linné, H, D, P, M, A.
Natica guppyana Toula, A.
Polynices duplicatus Say, H, D, P, M, A.
Turbo castaneus Gmelin, D, M, A.
Turbo dominicensis Gabb var., H, D.
Turbo crenulatoides Maury, D.
Turbo rhectogrammicus Dall, H, D, P.
Astralium praecursor Dall, H, D, P.
Collonia elegantula Dall, D.
Chlorostoma fasciatum Born, H, D, M, A.
Calliostoma willcoxiana Dall, H, D, P.
Calliostoma limulum Dall, H.
Calliostoma jujubinum Gmelin, H, D.
Dorsanum? plicatulum Bose, A.
Phos floridensis, n. sp., P.

A LIST OF SPECIES FROM ACLINE, FLORIDA

H. I. TUCKER and D. WILSON, DePauw University

The writers began studying the fauna and stratigraphy of the Caloosahatchie Pliocene formaton in 1928. The outcrops studied at Acline, Florida, are especially interesting. A number of new species are being described from this locality in the Bulletins of American Paleontology.

Species entirely confined to the Caloosahatchie are marked C; Miocene species, M; Pliocene species, P; species found in the Recent are marked R; those ranging from Miocene to Pliocene, T; those not reported above Miocene, N; these occurring in the Caloosahatchie but not confined to it are marked X.

Glycymeris americana (Defrance), R, M, X.
Glycymeris pectinata (Gmelin), R, M, X.
Arca (Barbatia) aclinensis, n. sp.
Arca scalarina Heilprin, C.
Arca chiriquensis Gabb, Miocene?
Arca lienosa Say, T, X.
Arca acompsa intermediata n. subsp., T.
Ostrea hartensis Sowerby, T, Pliocene?
Ostrea disparalis fredeai F. Hodson.
Crassatellites Gibbesii (T. and H), R, X, M.
Chama willcoxi Dall, C.
Echinochama arcinella (Linné), R, X, M.
Phacoides pensylvanicus (Linné), R, X, P.
Phacoides anodonta (Say), R, X, M.
Miltha caloosaensis (Dall), C.
Miltha disciformis (Heilprin), C.
Divaricella chipolana Dall var?
Diplodonta acclinis (Conrad), X, T.
Cardium oedalium Dall, X.
Cardium robustum Solander, R, R, M.
Cardium aclinensis, n. sp.
Dosinia elegans (Conrad), R, X, M.
Macrocallista nimbosa (Solander), R, X, P.
Macrocallista cf. M. Maculata (Linné).
Chione cancellata (Linné), R, X, M?
Chione cribraria (Conrad), T, X.
Chione latilirata (Conrad), R, X, M.
Venus campechiensis Gmelin, R, X, M.
Tellidora cristata (Recluz), R, X.
Mulinia sapotilla Dall, C.
Physa meigsii Dall, C.
Conus adversarius Conrad, T, X.
Conus proteus Hwass, R, X, M.
Conus floridanus Gabb, R, X, M.
Cancellaria conradiana Dall, R, X.
Cancellaria barreti Guppy, T, X.
Cancellaria tabulata Gardner and Aldrich, N.
Maculopepulum cf. M. floridanum (Heilprin).
Mitra cf. M. lineolata Heilprin.
Mitra sp.
Mitra sp.
Mitra sp.
Xancus sp.
Vasum horridum Heilprin, C.
Fasciolaria apicina Dall, X.
Fasciolaria gigantea Kiener, R, X, P.
Fasciolaria sparrowi Emmons, N.
Busycon pyrum (Dillwyn), R, X, M.
Busycon maximum Conrad, T, X.
Busycon planulatum (Dall) var.
Busycon perversum (Linné), R, X, M.
Busycon echinatum (Dall), C.
Melongena sp.
Solenosteira mengeana Dall, C.
Solenosteira vaughani aclinensis, n. subsp.
Fusinus caloosaensis (Heilprin), C.
Dorsanum plicatilum (Bose), N.
Murex rufus Lamarck, R, X, M?
Murex (Pteropurpura) textilis Gabb, T, X.
Typhis floridanus Dall, C.
Coralliophila sp.
Coralliophila lepidota Dall, P.
Cassis floridensis, n. sp.
Cypraca carolinensis floridana Mansfield.
Strombus pugilis alatus Gmelin, R, X.
Potomides (Pyrazisinus) sp.
Modulus modulus (Linné), R, X.
Turritella subannulata Heilprin, X, M, R.
Turritella apicalis Heilprin, X.
Turritella sp.
Solarium granulatum Lamarck, R, M.
Natica (Natica) sp.
Natica canrena (Linné), R, X, M.
Natica guppyana Toula, N.
Polynices duplicatus (Say), R, X, M.
Turbo castaneus Gmelin, R, X, M.
Chlorostoma fasciatum (Born), R, X.
Calliostoma sp.

THE PRINCIPAL BEDS OF UNDERCLAY IN THE COAL FIELDS OF INDIANA

GEORGE I. WHITLATCH[1]

Introduction. No single area in Indiana is so rich in ceramic resources as the coal-bearing area located in the western and southwestern part of the state. The underclays and shales found in association with most of the coals of this area are widely used in Indiana for the manufacture of ceramic products. In 1931, forty plants of the 101 ceramic plants in the state were using these materials.

Of the two ceramic materials, the underclays are the most important source of raw materials because of the greater variety of products which can be manufactured from them. In Indiana, the products manufactured from underclays include pottery, structural wares and refractories.

Because of the extensive and varied usages made of underclays in Indiana, it is of scientific as well as commercial interest to know the stratigraphical position and general character of the more important beds of underclay. The various state geological reports contain an abundance of information on clays, but such information is scattered and not readily accessible. In the following pages, the writer presents a summary of the chief underclay-bearing horizons of Indiana with reference to their relationship to the various coal beds. It must be borne in mind, however, that the information presented in the summary is very general and is intended solely as an index for rapid reference work; detailed information must be drawn from other sources.

The writer wishes to acknowledge his debt to the various writers on the subject of Indiana clays for supplementary information obtained from their publications.

Geologic Conditions. The Indiana coal field includes approximately 70,000 square miles or about one-fifth of the total area of the State. The rocks of this area belong chiefly to the Pennsylvanian system and consist of a great series of coals, sandstones, shales and underclays. All of the coals are found in the rocks of this system, except a thin and unimportant bed that occurs in the lowermost group of the Chester (Mississippian) series upon whose eroded surface the Pennsylvanian rocks rest.

The coal beds are interstratified with beds of shale, sandstone, underclay and limestone. The underclays normally underlie beds of coal. The thicknesses of the beds of underclay range from total absence, as in localities where the coal rests on shale or sandstone, to as much as 12 feet.

"The coal beds and their associated strata dip southwest at the rate of about 20 to 35 feet to the mile, except in the extreme north where

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"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

the dip is approximately west, and in the extreme south where the dip is northwest and north. The beds outcrop from east to west in the order of their age; the oldest extend farthest east and pass under younger beds toward the west.

"There are more than 20 beds of coal in the State; 15 have been mined locally and nine over large areas. The principal beds, named in the ascending order of stratigraphical position and age, are: Coal I, Lower Block, Upper Block, Minshall, Coal II, Coal III, Coal IV, Coal V, Coal VI, Coal VII, Coal VIII, Coal IX, Parker, Friendsville, and Aldrich."[2] All the coals belong to the bituminous class.

The Pennsylvania series of Indiana include the Pottsville, the Allegheny, and the post-Allegheny divisions. The rocks of the Pottsville division, which includes the Mansfield and the Brazil groups, rest unconformably upon the rocks of the Mississippian system. The Mansfield group consists largely of a basal conglomerate or sandstone, but also contains minor beds of shale and underclay and beds of coal.

POTTSVILLE DIVISION

Mansfield group. The principal beds of underclay in this group are found in association with Coal I and two riders of that coal bed. As the coals of this group were deposited in basins of relatively small area, the beds of underclay which occur beneath the coals are not continuous over very wide areas. The coals of the Mansfield group, therefore, have been difficult to correlate; in the southern part of the coal field at least three beds of coal and their associated strata have been recognized, while to the north, in the region of Greene and Martin counties, only one bed is recognizable as belonging to this group. The confusion which exists over this stratigraphical problem is unfortunate and for want of better correlation, the writer simply refers the coals to Coal I horizon. There is, however, a possibility that the Lower Block coal may be represented by one of the rider beds of Coal I in the southern part of the area.

Coal I usually rests upon beds of underclay which vary in thickness from three to six feet, the greater thicknesses being found in the southern part of the area. The underclays are gray to grayish-brown in color, of moderately fine texture, and almost always of good plasticity. Fossil plant imprints are very characteristic of these underclays. Fire tests of the clays from this horizon show that they are buff to tan-burning, are comparatively free of iron, and have an average refractoriness equivalent to Cone 10. Some of the underclays from the southern portion of the area are more refractory, however, and will withstand a temperature equivalent to Cone 20. The principal commercial uses that have been made of the clays from the horizon of Coal I include such products as stoneware, building tile, face brick, sewer pipe, conduits, flue lining, and chimney tops.

Brazil group. The Brazil group contains four mineable beds of coal —the Lower Block, the Upper Block, Minshall and Coal II. The underclay associated with the Lower Block coal is of variable quality. In the Brazil district (Clay County), the bed of underclay, upon which the Lower Block coal usually rests, is not of very great thickness and consists of a sandy underclay that is frequently of inferior quality; to the south and east of Brazil, in Greene and Martin counties, the thickness of the bed is greater and the clay is found to be fine-grained, plastic, and suitable for the manufacture of various ceramic wares, including terra cotta and pottery. The thicknesses of the bed range from one and one-half to 10 feet with the average thickness being about three to five feet. Commercial development of the underclays of this horizon has been limited.

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[2] "The Indiana Coal Fields." W. N. Logan, 11th Am. Rpt., Div. Geol., Dept. Cons., page 30, 1929.

The bed of underclay that is practically always found beneath the Upper Block coal is the best ceramic material in the state, from the standpoint of the large variety and the uniform quality of the products that are obtained from its use in ceramic manufacture. The underclay of this horizon is used extensively in the ceramic plants of the Brazil district and is shipped to numerous plants in other parts of Indiana and to points outside the state. The bed of underclay is typically developed in Clay and Parke counties. It is usually gray to dark gray in color, fine-grained, very plastic, comparatively free of grit and other impurities, moderately refractory, and buff-burning. The thickness of the bed is not very uniform and varies from two to as much as ten and one-half feet in thickness; the average thickness is about five feet. The underclay is well adapted to the manufacture of terra cotta and pottery and is very satisfactory for making building tile, face brick, conduits, sewer pipe, glazed tile, flue linings, and similar products.

The Minshall coal is underlain usually by a bed of underclay of good quality and of commercial thickness. The most typical development of this bed occurs in the region of Huntingburg (Dubois County). Here, the bed is about six feet in thickness and consists of an upper four-foot layer of buff-burning clay and a basal two-foot layer of red-burning clay. The buff-burning stratum of the bed is light gray in color, fine-textured, very plastic and sufficiently refractory for the manufacture of low-heat duty fire brick. Face brick are also made from this buff-burning layer. The basal, red-burning portion of the bed contains considerable sand, carbonaceous matter, and iron. The latter impurity is in the form of small, oolitic-like concretions. This basal layer is also used for making face brick.

Coal II is a coal of variable thickness and is entirely absent in certain areas, having been removed by erosion preceding the deposition of the rocks of the Allegheny division. A thin bed of underclay is frequently present beneath Coal II but the clay is not of commercial importance.

ALLEGHENY DIVISION

Staunton group. The Allegheny division is divided into three groups —the Staunton, the Petersburg and the Shelburn. The first of these formations contains Coal III, Coal IIIa and Coal IV. Coal III and Coal IIIa are best developed in the northern part of the Indiana coal field. The underclays associated with these coals are important ceramic materials. The underclay of Coal III is five to seven feet in thickness and is particularly well developed in Parke and Vermillion counties. The physical characters of the clay vary from a dark gray, soft, massive clay to that of a white, hard, massive, very siliceous clay which resembles a friable sandstone. This latter variety of underclay is found in the area between Newport and Montezuma and is used for the manufacture of a good grade of fire brick. The less siliceous deposits of the underclay are suitable for the manufacture of such structural wares as face brick, building tile and floor tile. The underclay of Coal IIIa averages about five feet in thickness. It is a gray, massive, fairly siliceous clay with good plasticity. The clay is moderately refractory and is used in the manufacture of sewer pipe and flue lining.

Coal IV usually rests upon a sandstone or a very hard and sandy shale or underclay. The underclay is not adapted to ceramic purposes. Coal IVa, which lies about 20 feet above Coal IV, is a thin rider vein that frequently rests upon several feet of very plastic, fine-grained, light gray underclay. The underclay merges into a massive, greenish-gray, sandy shale below. The underclay of this rider, although not used commercially at present, is adaptable to the manufacture of such structural wares as brick and tile.

Petersburg group. The Petersburg group contains three important coal beds—Coal V, Coal VI, and Coal VII. Coal V, the most important coal bed in Indiana, normally rests on shale or underclay. The underclay, where tested, has proven unsatisfactory for the manufacture of ceramic products. The thickness of the bed varies from a few feet up to as much as nine feet. The clay is greenish-gray to dark dray in color, is very sandy, and contains much pyrite.

Coal VI usually rests upon an underclay but the presence of shale at the base of the coal has been noted at several points. The thickness of the underclay bed is variable, ranging from a few inches to as much as seven feet; the average thickness, however, is between two and three feet. The clay is gray to dark gray in color, plastic, and often slightly sandy. There has been no commercial development of this bed of underclay, but fire tests which have been made of it show that, in places, the clay is adaptable to the manufacture of structural wares.

Underclay is usually found below Coal VII in commercial thicknesses. The underclay is generally dark brown in color, fine-textured, and plastic. Imprints of fossil plants are frequently very abundant in the upper part of the bed. The thickness of the underclay bed averages about five feet. The quality of the clay is variable, but where sufficiently free of iron, fluxes and other impurities, fire tests have shown that the underclay is adaptable to certain pottery and heavy clay products. As a commercial prospect this bed of underclay is not very good.

Shelburn group. The Shelburn group contains two beds of coal—Coal VIII and Coal IX. These beds of coal usually have some underclays associated with them but they are not of commercial importance.

POST-ALLEGHENY DIVISION

The post-Allegheny division, composed of the Merom and the Wabash groups, does not contain any underclays of commercial importance.

THE STRATIGRAPHY AND STRUCTURE OF A DEVONIAN LIMESTONE AREA IN CLARK COUNTY, INDIANA

GEORGE I. WHITLATCH and JOHN W. HUDDLE, Indiana University

Introduction. This paper is primarily the result of commercial prospecting for oil and gas in the Devonian limestone area of Clark County, Indiana, during the summer of 1931. In connection with the commercial work, special attention was given to the location of the western boundary of the Silurian rocks which also outcrop in that region.

This work on the Devonian and Silurian limestones has provided several new geologic sections heretofore unpublished, and some revision of sections published in earlier reports; the discovery of a Silurian inlier at a point west of any previously reported inliers; some new facts regarding the lithology, thickness, and persistence of the Devonian formations; the proposal of a name for the chert bed of the Silver Creek formation; and a structural map of a large portion of Clark County.

It is felt by the writers that data of this nature will be of interest and of value to future workers in this region; and since the commercial aspects of these investigations did not permit an exhaustive study, the following paper is presented with the sole idea of adding to, or revising, former reports on the geology of Clark County.

The writers wish to acknowledge their gratitude for assistance rendered by the Louisville Cement Company of Louisville, Kentucky, and the Indiana Department of Conservation, Division of Geology. Without the aid of these organizations, this work would not have been possible.

Review of Literature. In a brief paper of this nature, it is impossible to review in any detail the work of all the previous writers who have studied the Devonian formations of Clark County. The earliest work in this region was, probably, that of Increase A. Lapham in 1827. Since that time a number of writers have contributed to the knowledge of the Devonian rocks in Clark County, notable among whom were Hall, Borden, Foerste, Kindle, and Siebenthal. An able resume of the publications by these earlier workers may be obtained by consulting Cumings' "Nomenclature and Description of the Geological Formations of Indiana."[1] Of the reports by the above writers, the State report by Kindle,[2] published in 1900, and Siebenthal's State report on the Silver Creek hydraulic limestone, written in the same year,[3] have proved invaluable during the work upon which the following paper is based. Siebenthal's report is particularly valuable because of the geological

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[1] Cumings, E. R. Handbook of Indiana Geology, Part IV, pp. 405-570 (1922).

[2] Kindle, Edward M. "The Devonian Fossils and Stratigraphy of Indiana." 25th Ann. Report, Ind. Dept. Geol. Nat. Resources (1900).

[3] Siebenthal, C. E. "The Silver Creek Limestone of Southeastern Indiana." 25th Ann. Report, Ind. Dept. Geol. Nat. Resources (1900).

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

map which accompanies it and because of the number of detailed sections listed. These reports have been freely consulted in the preparation of the present paper.

Location and Topography. Clark County lies on the Ohio River in southeastern Indiana. Floyd and Washington counties lie to the west, and Jefferson and Scott counties lie to the north; the Ohio River forms the remainder of its boundaries.

In general, the topography of Clark County is that of a dissected plateau, sloping gently toward the west, where rises the Knobstone escarpment. The county is drained by two major streams, Silver Creek and Fourteen Mile Creek. Both streams flow in a southerly direction and empty into the Ohio River.

Physiographically, Clark County is situated upon the Muscatatuck Regional Slope, the Scottsburg Lowland, and the Norman Upland. The eastern part of the county lies within the western part of the Muscatatuck Slope, the western boundary of that unit being given as "the divide between Fourteen Mile and Silver Creeks in Clark County."[4] In this eastern part of the county, the uplands are typically quite flat between streams and the gentle southwestern slope is not perceptible to the eye. The major drainage line, Fourteen Mile Creek, is canyon-like in character. Its tributaries entering from the east are much longer than those entering from the west, due probably to the dip of the underlying strata. Some underground drainage has been developed in the underlying limestones. Sinkholes are fairly numerous and small caves are frequently found in this part of the county. To the south, the uplands pitch off abruptly at the bluffs of the Ohio River in an escarpment about 400 feet in height.

As a regional slope, the eastern part of Clark County merges rather indistinctly into the Scottsburg Lowland on the west. In this lowland area the topography has a rolling character with flat-topped divides developed upon the underlying Devonian shale. The immediate relief is usually small and the streams have developed fairly wide and flat valleys. Subterranean drainage is also found in this part of the area, but the development of such drainage is somewhat greater than it is farther to the east. "Indian Cave," one of the largest caves in the area, is found just west of the city limits of Charlestown.

The Scottsburg Lowland area of Clark County is bounded on the west by the Knobstone escarpment which marks the eastern boundary of the Norman Upland. The rise into the rugged topography of the Knobs country is rather abrupt. The eastern face of the escarpment is not an unscalable bluff, however, but is a steep slope which rises rapidly to heights of 400 to 600 feet above the adjacent lowlands. The Knobs country is maturely dissected and has a well developed surface drainage cut deeply into the underlying Mississippian shales and sandstones.

The greater part of Clark County has been glaciated, but no large amount of drift has been left over its surface. The principal impress left by the glaciers is confined, in the main, to the uniform, flat-topped appearance of the upland divides in some parts of the county.

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[4] Malott, C. A. "The Physiography of Indiana." Handbook of Indiana Geology, Part II, page 86 (1922).

The area investigated in Clark County by the writers comprised about 100 square miles, lying in the eastern and central portions of the county. The boundaries of the area are roughly as follows: The north and south boundaries are approximately on parallel lines which pass through Memphis and Watson respectively; the east and west boundaries, on parallel lines through the mouth of Fourteen Mile Creek and Speed respectively.

GEOLOGY

Rocks of four geological periods outcrop in Clark County. In order from east to west, these groups are the Ordovician, Silurian, Devonian, and Mississippian. Outcrops of the Ordovician and Silurian limestones are limited, in the main, to that portion of the county east of Fourteen Mile Creek and the Ohio River bluff as far south as Utica. The Mississippian rocks in the county consist of the Borden group of shales, sandstones and limestones which occupy an irregular area two to eight miles in width along the western border of Clark County. The remaining and major portion of the county is occupied by the rocks belonging to the Devonian period.

For the sake of clearness in later discussions, the geological section of the Devonian period, as represented in Clark County, is given below with a short description of the lithologic character of each formation.

Geological Section

Devonian—
- New Albany Shale
- Beechwood limestone
- Silver Creek limestone
- Jeffersonville limestone

Silurian—
- Louisville limestone

New Albany Shale. The New Albany shale is the uppermost member of the Devonian series found in Clark County. It is a dark gray to black, fissile, in places sheety shale which often contains a high percentage of bituminous matter. The thickness of the shale varies in Clark County from complete absence in the eastern part of the county to a maximum thickness of over 130 feet in the region near Henryville. The outcrop of the shale lies roughly between Fourteen Mile Creek on the east to Silver Creek on the west.

The New Albany shale lies disconformably upon the underlying Devonian limestones and the writers found the contact of the shale and limestone to be unreliable as a datum plane for structural mapping.

Beechwood Limestone. The Beechwood limestone is "that bed of white to gray crystalline limestone which overlies the cement rock (Silver Creek limestone), which underlies the New Albany Black shale, and which by various writers has been alluded to as the Crinoidal limestone, and to distinguish it from a crinoidal layer in the Corniferous (Jeffersonville limestone), as the Upper Crinoidal limestone."[5] The Beechwood is referred to as the "Sellersburg" by Siebenthal, from whose report the above quotation was taken, but more recent work by Butts,[6] who proposed the name, has warranted the application of the name of "Beechwood" to this formation

The Beechwood limestone, as exposed in Clark County, is easily recognized by its hard, massive, coarsely crystalline characters and the abundance of fossil crinoid plates and stems that weather into relief on exposed surfaces. The limestone is usually thin, the average thickness being about four feet, although in some places the thickness is as much as ten feet. The Beechwood is a very persistent formation in Indiana, being present in practically every section that exposes both the New Albany shale and the Silver Creek limestone. The overlying shale often slumps down over the Beechwood, thus obscuring the bed where thin, and careful search is then necessary to reveal its presence in the section.

At or near the base of the Beechwood limestone there is generally a conglomeritic band characterized by shining black pebbles that are clearly rounded and water-worn. This band is frequently very sandy with the pebbles imbedded in this arenaceous matrix. In places, the conglomeritic band is as much as six inches in thickness and forms a definite stratum intercalated between the Beechwood and the Silver Creek limestones; at other points, the band is thin and appears to be distinctly related to the Beechwood formation. The natural conclusion is that this band represents a basal conglomerate, but certain features seen in the character of the pebbles and the physical appearance of the exposures of this band do not, at present, warrant a definite theory of its origin. The conglomeritic band is well developed in the outcrop exposed along a tributary of Sinking Fork Creek in Section 136 (see Section No. 33).

Because of the thinness of the Beechwood member, its persistence over a considerable area, and its easily recognized lithologic characters, this limestone serves as a very good key horizon for structural mapping.

Silver Creek Limestone. The Silver Creek limestone lies between the Beechwood limestone and the Jeffersonville limestone. It is typically developed in the region of Silver Creek, Clark County, and has received its name from that fact. The limestone is often termed "cement rock" because of its once extensive use for the manufacture of cement in Clark County.

The Silver Creek limestone is typically a fine-grained, bluish to drab, soft, fairly homogeneous, argillaceous magnesian limestone. It occurs in fairly massive beds, the average total thickness of which is about 15 feet in the area investigated in Clark County, but in places the thickness is reduced to as little as nine and one-half feet. According to Butts,[7] there is a hiatus between the Beechwood and Silver Creek limestones and this may account for the variable thicknesses of the two formations. As is shown by sections below, the Beechwood limestone is thickest where the normal thickness of the Silver Creek is reduced and vice versa. Regionally, the limestone thins to the north and, according to Siebenthal, disappears in the northern part of Scott County.

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[5] Siebenthal, C. E. Op. cit., page 341.

[6] Butts, Chas. "Geology of Jefferson County (Ky.)." Ky. Geol. Surv., Ser. IV, vol. 3, pt. 2 (1915).

[7] *Ibid.*, p. 192.

Previous writers on the Devonian limestone of Clark County have usually noted the presence of a cherty bed in the upper part of the Silver Creek formation. The bed is commonly referred to, in the literature, as "bastard rock" and is usually listed in each section as separate and distinct from the true "cement rock." Siebenthal[8] believed that this chert bed was deposited contemporaneously with the Beechwood limestone.

This cherty horizon of the Silver Creek limestone received special attention during the work of the past summer. The bed was found to be a very distinct lithologic unit that varies from a few feet to as much as fourteen feet in thickness. In only a few places was the chert bed found to be absent from the section. The bed normally contains an abundance of chert, often in distinct horizontal bands, imbedded in a matrix of drab, fine-grained limestone that is lithologically similar to the Silver Creek limestone. Although some chert nodules are found scattered throughout the entire thickness of the Silver Creek formation, this particular chert bed, which occurs in the uppermost part of the formation, is characterized in its basal portion by the distinctly bedded character and extreme abundance of the chert as compared with that found in the lower part of the Silver Creek formation. In most cases the line of separation between the chert bed and the true "cement rock" is well marked; and in a few cases an inch or so of shale separates the two parts of the formation.

It is believed by the writers that the cherty portion of the Silver Creek limestone was deposited contemporaneously with the limestone matrix and that it is not a result of solution and replacement processes. The cherty bed was evidently deposited under slightly different conditions from those prevailing during the deposition of the lower, less cherty part of the formation. Contrary to Siebenthal's suggestion that the chert bed was deposited in Beechwood time, the writers have found typical Beechwood limestone overlying the chert beds at a number of places. This fact renders Siebenthal's view untenable.

Since this chert bed is a fairly persistent and distinct lithologic unit and since the earlier writers have seen fit to discriminate between the chert bed and the "cement rock," it is proposed that the bed be called the *New Chapel chert bed of the Silver Creek limestone.* The name "New Chapel" is taken from a small country church located in the southwest quarter of the southeast quarter of Sec. 37, Clark Grant, Clark County, Indiana. In a roadcut, just a few yards east of the church, the chert bed is well exposed near the top of a hill. (See Section No. 10 and Fig. No. 1.) Unfortunately, the type section selected for this cherty bed is not entirely satisfactory since the overlying Beechwood limestone is absent and the base of the cherty horizon is covered. Better exposures of the cherty bed are to be found at Watson (see Section No. 9) and north of Charlestown (see Section No. 33), where the overlying and underlying formations are present. Selection of either of these exposures as a type section was preferable, but due to the fact that the name "Watson"[9] was preoccupied and that the exposure north of Charlestown occurs on an unnamed stream, neither exposure could be selected as a type section.

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[8] Siebenthal, C. E. *Op. cit.*, p. 342.

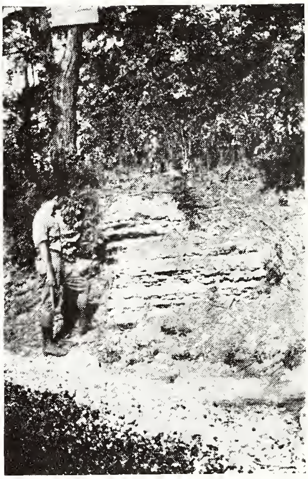

Fig. 1. An outcrop of the New Chapel chert bed at the type locality. Note the abundance of distinctly bedded chert.

Jeffersonville Limestone. The Jeffersonville limestone lies beneath the Silver Creek limestone and above the Louisville limestone (Silurian) in the part of Clark County investigated by the writers. In other parts of the state the Pendleton sandstone or the Geneva dolomite occupies the base of the Devonian section, but no certain representatives of either of these formations were distinguished in any of the sections studied by the writers.

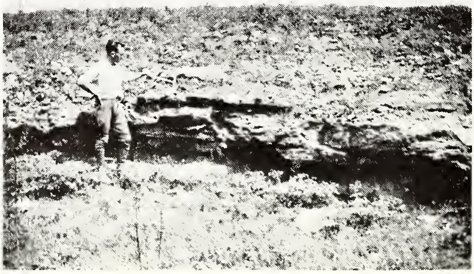

Fig. 2. Outcrop of Devonian limestone showing contact of Silver Creek limestone and *Stropheodonta demissa* zone of Jeffersonville limestone. Hammer rests at contact. Note the flaggy character of the Jeffersonville limestone, characteristic of weathered portions of the upper zone of that formation.

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[9] "*Watson bed*" was used by Rowley (Am. Jour. Sci., 4th ser., vol. 41, p. 318, 1916) for a part of the Silurian Edgewood limestone of Missouri. *New Chapel* has not been preempted.—Personal communication from M. Grace Wilmarth, Secretary, Comm. Geol. Names, U. S. G. S., Oct. 15, 1931.

Lithologically, the Jeffersonville limestone may be divided into three parts: (1) an upper, gray, shaly, very fossiliferous limestone, characterized by an abundance of *Athyris fultonensis*, *Stropheodonta demissa*, and several species of *Fenestella* and other bryozoa; (2) a middle, white to blue-gray, hard, massive limestone that composes the greater part of the formation; and (3) a basal, brown to blue-brown, crystalline limestone characterized by many corals (coral bed). (Fig. 2.)

The upper, shaly limestone is apparently the "*Stropheodonta demissa* zone" of Kindle and Siebenthal as it is the only portion of the Jeffersonville formation in which an abundance of this fossil was found by the junior author; many of the fossils in this zone are stained a dark purplish-red, particularly *Stropheodonta demissa*. The writers are inclined to agree with Kindle and Siebenthal that this zone belongs to the Jeffersonville limestone, but wish to suggest that it may represent the base of the overlying Silver Creek formation. In most of the sections examined, including the section at the Louisville Cement Company quarry at Speed, the physical relationship of this zone seems to be more intimately associated with the Jeffersonville limestone than with the Silver Creek limestone. However, at the old Clark Mill quarry (see Section No. 5 below) the relationship seems to be reversed.

On account of the existing doubt regarding the age of the "*Stropheodonta demissa* zone," the junior author collected and has identified the following fossils from this zone:

List of Fossils From the *Stropheodonta demissa* Zone

	Utica Township School (see Sec. No. 15)	Louisville Cement Co. quarry at Speed (see Sec. No. 2)	Diedrich Farm SE¼, Sec. 132
Athyris fultonensis (Swallow)	x	x	x
Aulopora serpens Goldfuss	x		x
Camarotoechia tethys (Billings)	x		
Crytina hamiltonensis Hall	x		
Fenestella verrucosa Hall		x	
Hadrophyllum d'orbignyi E. and H.	x	x	x
Leptaena rhomboidalis (Wilckens)	x	x	x
Phacops sp.			x
Rhipidomella livia (Billings)	x		
R. vanuxemi Hall	x	x	x
Schizophoria striatula (Schlotheim)	x	x	x
Spirifer byrnesi Nettleroth	x	x	x
S. grieri Hall	x		
S. macrus Hall	x		
S. varicosus Hall	x		x
S. varicosus hobbsi Nettleroth			x
Stropheodonta demissa (Conrad)	x	x	x
S. inaequistriata (Conrad)	x		x
Terebratula jucunda Hall		x	

Many specimens of *Fenestella* and other bryozoa collected from this zone have not been identified as yet because of their poor state of preservation.

Practically all the fossils listed above have been previously reported from the Jeffersonville formation. Some few, such as *Stropheodonta demissa, Athyris fultonensis, Rhipidomella vanuxemi, Leptaena rhomboidalis, Spirifer byrnesi* and *Spirifer varicosus,* have been reported from both the Jeffersonville (Onondaga) and the Silver Creek (Hamilton) formations. Species that have been reported only from the Jeffersonville (Onondaga) formation include *Camarotoechia tethys, Rhipidomella, livia, Hadrophyllum d'orbigny. Spirifer varicosus hobbsi* has never been reported from the Jeffersonville limestone but has been reported by Savage,[10] from the base of the Silver Creek (Hamilton) formation, and by Nettleroth,[11] from the Beechwood (Hamilton) limestone. In as much as this fossil is a variety of *Spirifer varicosus* which is common in the Jeffersonville limestone, there appears to be no reason why the varietal form should not be present there. With this possible exception, the faunal affinities of the "*Stropheodonta demissa* zone" are with the Onondaga rather than Hamilton, and the shaly zone is regarded, therefore, as belonging to the Jeffersonville limestone rather than with the Silver Creek formation.

The middle, massive, white, crystalline portion of the Jeffersonville limestone is typical of the lithological character of the greater part of that formation. Directly below the *Stropheodonta demissa* zone and in the uppermost part of this middle portion occurs the "*Spirifer acuminatus* zone" of Kindle. This zone was found to be present wherever the top of the Jeffersonville horizon was exposed and may be as much as five feet in thickness. In addition to the abundant *Spirifer acuminatus,* the zone also contains many specimens of *Stropheodonta concava.* Near the base of the middle, crystalline portion of the Jeffersonville horizon, a few feet above the basal coralliferous portion, occurs the "*Spirifer gregarius* zone." This zone varies from a few inches to a little more than a foot in thickness and is rather easily recognized. The zone has been mentioned by Kindle, Savage, Siebenthal and others. Savage[12] correlates this zone with a similar one in the Grand Tower limestone of southwestern Illinois.

The basal portion of the Jeffersonville formation is the so-called "coral reef of the Falls of the Ohio." Cumings regards this coralliferous zone as a coral bed or layer rather than a true coral reef. "A coral reef refers to an upstanding mass on the sea bottom. The coral reef of the Jeffersonville limestone shows no evidence of ever having been such an upstanding mass, but is, rather, a wide-spread bed, from three to ten feet in thickness, that is composed chiefly of many species of corals." [13] To the knowledge of the junior author, no true reef structure has ever been found at this horizon and the term "coral bed" is, therefore, much more appropriate in referring to the coralliferous zone of the Jeffersonville formation. This coral bed of the Jeffersonville limestone is easily distinguished from that of the underlying Louisville (Silurian) limestone by the presence of the "chain coral" or *Halysites* in the latter and total absence of that form in the Jeffersonville limestone. The blue-brown color of the coralliferous zone of the Jeffersonville limestone is also distinctive.

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[10] Savage, T. E. "The Devonian Rocks of Kentucky." Ky. Geol. Surv., Series IV, Vol. 33, p. 88 (1930).

[11] Nettleroth, Henry. "Kentucky Fossil Shells." Monograph, Ky. Geol. Surv., p. 122 (1889).

[12] Savage, T. E. *Op. cit.*, p. 88.

[13] Cumings, E. R.—oral communication.

Louisville (Silurian) Limestone. The Louisville limestone is the uppermost member of the Silurian rocks exposed in Clark County, Indiana. Only the upper part of the Louisville limestone is exposed in most of the area studied, although in the eastern part of the area and in the region of the Ohio River extensive sections of the Silurian rocks are exposed.

The upper part of the Louisville limestone is a blue-gray, massive, argillaceous limestone characterized by an abundance of *Halysites*, and several small species of *Favosites* and *Zaphrentis*. This horizon may represent the coral bed that is found at the top of the Louisville limestone in the vicinity of Louisville, Kentucky. The lower part of the Louisville formation is a light brown, fine-grained, crystalline limestone. The "*Stromboides* zone" is about twenty feet below the top of the formation and the "*Pentamerus oblongus* zone" is near the base of the formation. Where exposures were accessible for accurate measurement, the Louisville limestone was determined as being 50 to 60 feet in thickness, in the area studied.

An inlier of Louisville limestone was discovered along Pleasant Run in Sections 92, 93, and 94. This "window" of Silurian rock is worthy of special note since it has not been reported heretofore. The inlier is considerably west of any previously reported inliers.

FIELD PROCEDURE

The writers spent a total of seven weeks in Clark County collecting the data upon which this paper is based. The time was divided approximately as follows: two weeks in reconnaissance with aneroid barometer; three weeks in detailed surveying with a telescopic alidade and plane table; two weeks and a half rechecking sections and obtaining additional data in critical areas, constructing maps, identifying fossils, and doing other types of office work.

The reconnaissance work was done with a standard five-inch "Tycos" aneroid barometer. During the two weeks of reconnaissance work, the writers drove over practically all of the Devonian area of Clark County examining the more prominent outcrops in quarries, road cuts, along streams, and in similar exposed places. Two days were also spent on the Kentucky side of the Ohio River for the purpose of obtaining greater familiarity with the stratigraphy of the region. All outcrops were noted and aneroid elevations were taken upon one or more of the exposed horizons. Locations of outcrops were made by means of a farm plat map supplied by the Clark County State Bank of Jeffersonville.

After sufficient reconnaissance work had been done to show the most promising area for possible gas and oil structures, a detailed survey of approximately 100 square miles was made with the telescopic alidade and plane table. Primary traverses, totaling about 40 miles, were run along all the principal roads of the area; side shots were made from these primary traverses to all possible outcrops, in order to obtain the elevations of the key horizon. The top of the Silver Creek lime-

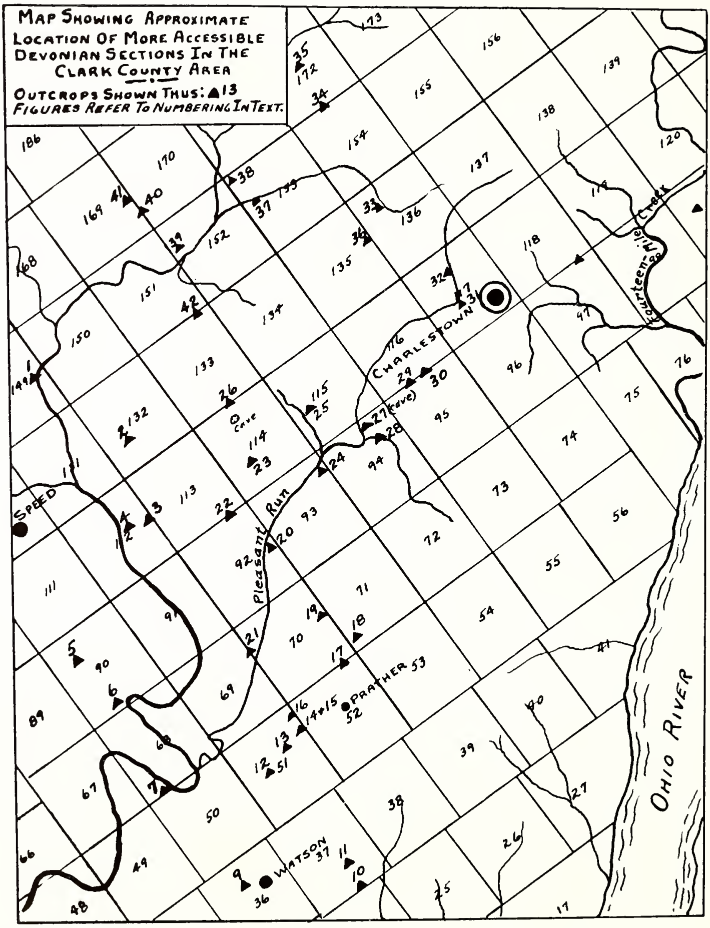
Map Showing Approximate Location Of More Accessible Devonian Sections In The Clark County Area
Outcrops Shown Thus: ▲13
Figures Refer To Numbering In Text.
Charlestown
Speed
Pleasant Run
Fourteen-mile Creek
Ohio River
Prather
Watson
Cave

Fig. 3. Outline map of a part of the Devonian limestone area in Clark County, Indiana, showing the approximate location of the more accessible outcrops between Charlestown and Speed.

stone (including the New Chapel chert bed) was used as the key horizon. Elevations were often taken on the tops of other formations exposed in a section, thus insuring greater accuracy in determining the thicknesses of various formations as well as aiding in later interpolations necessary to the construction of the structural map. The railroad elevations used as permanent bench marks from which all traverses were run as follows: Charlestown, B. & O. R. R., 590 feet; Sellersburg, Penn. R. R., 478.8 feet; Watson, B. & O. R. R., 503 feet; and Memphis, Penn. R. R., 489.7 feet.

With the aid of the plane table sheets and the farm plat map, each outcrop was accurately located upon a base map prepared from a copy of the county road commissioner's map. The elevations of the key horizon or interpolations to that horizon were then placed upon the map and the contours drawn upon the assembled data. In the final construction of the structural map, it was found that the data obtained from the first traverses were slightly inadequate to clearly delineate the structure and an additional week was spent in securing these necessary data.

The instrument work, construction of the structural map, and a portion of the geologic work necessary to the preparation of the present paper are due to the efforts of the senior author; the paleontological and stratigraphical phases of the work are almost entirely due to the ability of the junior author. Field assistance was given by Mr. George R. Freed during the survey work with the alidade.

LOCAL DETAILED SECTIONS

The following list of detailed sections from the Devonian limestone area of Clark County records, for the most part, new geologic sections not previously published. Each section, with only a few exceptions, is supplemented by one or more elevations taken at the contact of various formations exposed in the outcrop. In a few instances earlier reported sections are included either because of a desire to correct some discrepancy in former work, or because the section is needed to show the character of the stratigraphy.

Locations of the majority of these sections are shown on the accompanying map, (Fig. 3).

Speed and Vicinity

Section No. 1. On the west bank of Silver Creek, where the pike road turns east, near the center of Section 149, the following connected section is exposed along the road and in the creek bank:

New Albany shale	about 15 ft.
Beechwood limestone	3 ft.
Silver Creek limestone	4 ft.
Covered	20 ft.
Jeffersonville limestone	6 ft. to creek level

Elevation on the top of the Beechwood...........464 ft. A. T.

Section No. 2. The quarry of the Louisville Cement Company at Speed, located near the center of Section 132, shows the following section:

New Albany shale	5 ft. plus
Beechwood limestone	3 ft.
Silver Creek limestone	16 ft.
Jeffersonville limestone	33 ft.
Louisville (Silurian) limestone (in sump)	6 ft.

Elevation on top of the Beechwood...........486 ft. A. T.

The New Chapel chert bed is not well developed in this section and is confined to about four feet of moderately cherty Silver Creek limestone. The Jeffersonville limestone of the section includes a three-foot layer of corals at its base. Coralliferous Louisville limestone containing *Halysites* is found in a drainage sump at the west side of the quarry.

Section No. 3. The abandoned quarry of the old United States Cement Mill, near the center of the east line of Section 112, lies on the east side of Silver Creek, at the forks of the Charlestown-Sellersburg road. A section taken at this quarry shows:

New Albany shale....................	6 ft. plus
Beechwood limestone	3 ft.
Silver Creek limestone..............	13 ft. to quarry floor
Elevation on top of the Silver Creek formation...	486 ft. A. T.

The base of the Silver Creek limestone is not exposed in this quarry. The New Chapel chert bed of the Silver Creek is represented in this section by four to five feet of moderately cherty limestone that is somewhat harder than the typical "cement rock." The chert is not very distinctly bedded and occurs most abundantly in the lower part of the New Chapel bed. (Fig. 4.)

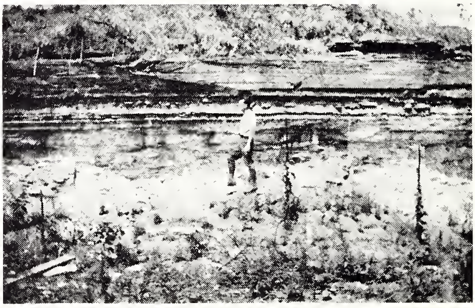

Fig. 4. Exposure of the Silver Creek formation at the old quarry of the U. S. Cement Mill, east of Sellersburg, Ind. The base of the New Chapel chert bed is marked by the senior author's hammer.

Section No. 4. Just about 1000 feet west of the above section the Charlestown-Sellersburg road crosses Silver Creek. The east bank of that stream exposes the following section:

New Albany shale	
Beechwood limestone	2 ft.
Silver Creek limestone................	15 ft.
Covered	25 ft.
Jeffersonville limestone	8 ft. to creek level
Elevation on top of the Silver Creek limestone.....	470 ft. A. T.
Bench mark, middle of floor, west end of Silver Creek bridge	477.2 ft. A. T.

Section No. 5. A road metal quarry is now operating at the site of the former Clark County Cement Mill in the northwest quarter of

Section 90, about one-half mile south of the center of Sellersburg. A section of the north face of the quarry is as follows:

New Albany shale	3 to 4 ft.
Beechwood limestone	4 ft.
Basal conglomerate	3 to 4 in.
Silver Creek limestone	14 ft.
Jeffersonville limestone	33 ft.
Louisville limestone	16 ft.
Elevation on top of the Beechwood limestone	484.5 ft. A. T.
Elevation on top of the Jeffersonville limestone (south side of quarry)	466.6 ft. A. T.

The cherty New Chapel bed of the Silver Creek formation is five feet thick at this point. A shaly zone, about one foot in thickness, containing an abundance of *Chonetes* species, separates the cherty bed from the lower eight feet of blue-gray, typical "cement rock." A zone of shaly, brownish limestone containing an abundance of *Stropheodonta demissa* is found in the top of the Jeffersonville limestone.

The upper five feet of the Jeffersonville limestone is not very crystalline. *Spirifer acuminatus* occur abundantly five feet below the top of the formation. The coral layers in both the basal portion of the Jeffersonville and the upper portion of the Louisville limestones are well developed at this quarry.

Section No. 6. Southeast towards Watson, on the road which passes the above mentioned quarry, in the southeast quarter of the southwest quarter of Section 90 is an abandoned road quarry on the farm of L. Dryer. This quarry exposes 22 feet of Jeffersonville limestone to the quarry floor. The upper 10 feet of the section is typical white, crystalline limestone but the lower 10 to 12 feet is composed of dark bluish-gray, crystalline limestone that scarcely resembles typical Jeffersonville limestone.

The floor of the quarry has collapsed in a number of places because of subterranean drainage channels.

Section No. 7. Southeast of this quarry, in the southwest quarter of Section 68, where the Watson-Sellersburg road crosses Silver Creek, Jeffersonville limestone is exposed in the west bank of that creek. About 12 feet of limestone is exposed to creek level at this point.

Section No. 8. South of Sellersburg, near the northeast quarter of the northwest quarter of Section 34 (about one mile south of Cementville), is a road metal quarry operated by K. Graves. The section at this quarry is as follows:

New Albany shale and soil	6 to 8 ft.
Beechwood limestone	3 to 8 in.
Silver Creek limestone	26 ft.
Jeffersonville limestone	6 ft. to quarry floor

The geological section exposed in this quarry presents a rather interesting stratigraphical problem. Directly beneath the New Albany shale is a very thin limestone which the writers have correlated as Beechwood. Although the limestone is not exactly typical of normal Beechwood, its coarsely crystalline character, dark gray color, and the presence of a few fossil crinoids are sufficient to warrant correlation with that formation.

The Silver Creek formation of this section is extremely abnormal in thickness and consists of two distinct beds, the New Chapel chert bed and the "cement rock." The New Chapel chert bed is fourteen feet in thickness. The chert is extremely abundant in the lower part of the bed and occurs in fairly regular bands, particularly in the basal four feet of the bed. The amount of chert decreases toward the top of the bed until the uppermost four or five feet are almost devoid of chert. The chert is in a matrix of bluish gray limestone that is practically as fine-grained as the true cement rock below, although it was noted that the limestone is somewhat more crystalline towards the top of the bed. Fossils are fairly abundant in this cherty bed.

A thin shale parting, one to two inches in thickness, separates the New Chapel chert bed from the lower bed of bluish-gray, fine-grained Silver Creek "cement rock" which is 12 feet in thickness. This bed of limestone is, lithologically, typical Silver Creek and contains only a few scattered nodules of chert.

As is shown in a following section taken at Watson, unmistakable Beechwood limestone does occur over the New Chapel horizon at that point, and from that evidence it is felt that the New Chapel chert bed should be correlated with the Silver Creek limstone. Certainly it was not deposited contemporaneously with the Beechwood limestone, as Siebenthal suggested.

Watson and Vicinity

Section No. 9. In the center of the north half of Section 36, a few yards east of where State Highway No. 62 crosses the north-south road to Sellersburg and Watson, is located the abandoned quarry of the old Queen City Cement Mill. A section of the north side of the quarry is as follows:

New Albany shale	5 ft.
Beechwood limestone	3 ft.
Covered	2 ft.
Silver Creek limestone	9½ ft.
Covered below	

Elevation on top of the Beechwood limestone......471 ft. A. T.

The conditions at this quarry are very similar to those described in the preceding section. The uppermost four feet of the Silver Creek formation is composed of a fine-grained, bluish gray limestone that contains an abundance of chert. This upper bed of cherty limestone is the New Chapel chert bed. It is not separated from the lower part of the Silver Creek formation by any definite break but the line of separation between the two beds is rendered very distinct by the absence of chert below a certain level and the abundance of chert above this level. The limestone matrix in which the chert occurs is lithologically the same as the limestone in the lower bed.

About fifty feet north of the face of the quarry, typical Beechwood limestone is exposed to a thickness of approximately three feet. Although the base of the Beechwood is not exposd, only two feet of cover exists between the base of the outcrop and the top of the Silver Creek limestone in the quarry; and consequently, the total thickness of the Beechwood cannot exceed five feet at this point.

Siebenthal[14] reported a thickness of 12 feet of "cement rock" (Silver Creek) and eight feet of "cherty bastard rock" (Silver Creek-New Chapel chert bed) from this section. The present condition of the quarry is not conducive to very accurate measurements of the entire section of Silver Creek limestone exposed, but Siebenthal's figure for the thickness of the chert bed is evidently in error as six feet would be the maximum thickness possible by adding the thickness of the covered zone.

Section No. 10. The New Chapel Methodist Church is located east of Watson, in the southwest quarter of the southeast quarter of Section 37. State Highway No. 62 passes on the south side of the church. At the east end of the church cemetery, where the highway passes down a long hill through a shallow cut, the following section is exposed along the north side of the cut:

Soil containing chert	4 ft.
Cherty Silver Creek limestone	6 ft.
Covered	8 ft.
Jeffersonville limestone	11 ft.
Covered	22 ft.
Jeffersonville limestone	1 ft.
Covered	9 ft.
Louisville (Silurian) limestone	2 ft.to stream bed

Elevation on top of the Silver Creek limestone....525 ft. A. T.

The six-foot bed of Silver Creek limestone exposed at the top of the hill in this section is a very cherty, fine-grained limestone. The chert occurs in distinctly horizontal layers. It is from this exposure of cherty Silver Creek limestone that the name "New Chapel chert bed" has been taken. (see Fig. 1) As a type section, the exposure is unsatisfactory in that the Beechwood limestone is absent from above the bed and the contact of the cherty bed with the lower part of the Silver Creek formation is covered. However, the accessibility of the outcrop and the typical development of the cherty bed at this point do much to excuse the other unsatisfactory features of the section.

Section No. 11. A thousand feet north of the above section, on the west side of a dirt road, is an abandoned road metal quarry. The section exposed in the quarry is as follows:

Soil, chert, and silicified fossils	12 ft.
Silver Creek limestone	2 ft.
Jeffersonville limestone	18 ft. plus

The base of the quarry exposes the blue-brown coralliferous horizon of the Jeffersonville but it was not possible to determine the total thickness of that horizon at this place. Judging by the total thickness of Jeffersonville limestone exposed at New Chapel church, just to the south, the coral horizon must be of considerable thickness in this area.

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[14] Siebenthal, *Op. cit.*, p. 387.

Prather and Vicinity

Section No. 12. In the vicinity of Prather several good sections are exposed. On the farm of R. Hilton, in the southeast quarter of the northwest quarter of Section 51, north of State Highway No. 62, is a small abandoned road quarry. The section at this quarry is as follows:

New Albany shale	about 3 ft.
Beechwood limestone	10 ft.
Basal conglomerate	6 in.
Silver Creek limestone	6 ft.
Covered below	

Elevation on top of the Beechwood limestone......490 ft. A. T.

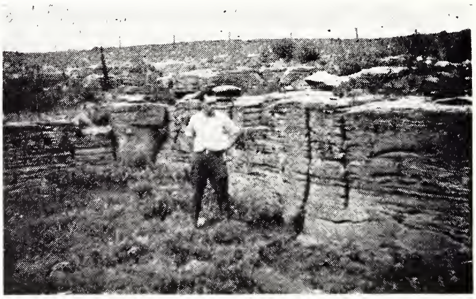

Fig. 5. Exposure of Beechwood limestone in old quarry on R. Hilton farm near Prather, Ind. Note massive character of this limestone.

This is one of the greatest thicknesses and one of the most typical sections of Beechwood limestone seen in this area. (Fig. 5.) The bed is massive, contains an extreme abundance of crinoid fossils, and is very coarsely crystalline.

The New Chapel chert bed of the Silver Creek formation is represented at this quarry by three to four inches of very cherty limestone that occurs in the uppermost part of that formation. This extreme thinness and often total absence of the cherty bed is a common occurrence at places where the Beechwood limestone reaches its greatest thicknesses. Conversely, it has been noted that the Beechwood limestone is thin in the sections where the New Chapel chert bed is present in any great thickness. These facts are indicative of a rolling upper surface of the Silver Creek formation upon which the Beechwood limestone was deposited disconformably.

Section No. 13. About 700 yards east of this quarry, an outcrop of 10 feet of Beechwood limestone is exposed along State Highway No. 62 in the west bank of a small gully. The Silver Creek limestone is exposed below, and the New Albany shale rests on top of the Beechwood. The New Chapel chert bed of the Silver Creek limestone was not noted.

Elevation on top of the Beechwood limestone..........501 ft. A. T.

Section No. 14. In front of the Utica Township school, which is located in the southeast quarter of the northeast quarter of Section 51, the following section outcrops on the south side of State Highway No. 62:

New Albany shale and soil	2 ft. plus
Beechwood limestone	5 ft.
Silver Creek limestone	7 ft.
Covered below	

Note that the Beechwood limestone has thinned from ten feet to five feet between this point and the preceding outcrop, a distance of approximately 500 yards. The New Chapel chert bed of the Silver Creek is absent from this section.

Section No. 15. Just a few yards east of No. 14 on the east side of the intersection of State Highway No. 62 and a north-south county road, the following section is exposed:

New Albany shale and soil	3	ft. plus
Beechwood limestone	5½	ft.
Silver Creek limestone	9½	ft.
Jeffersonville limestone	1	ft. exposed

Elevation on top of the Beechwood limestone..........506 ft. A. T.

This is one of the smallest thicknesses of Silver Creek limestone observed in the area studied. The New Chapel chert bed is absent.

Section No. 16. About 500 yards north of the cross-roads mentioned in Section No. 13 is a small, abandoned road quarry, on the west side of the county road. The quarry is entirely in the Jeffersonville limestone and exposes some twenty feet of strata. Most of the limestone is white, massive and crystalline, although in places it is rather lithographic. Some chert was observed in the limestone. The lower portion of the quarry exposes a blue-brown coralliferous layer, thus indicating proximity to the base of the Jeffersonville formation.

Section No. 17. A few yards north of the small village of Prather, the Baltimore and Ohio Railway passes through a small cut at an elevation of 530 ft. A. T. This cut exposes some thirty feet of New Albany shale but no limestone was observed. About 800 feet north of this point, in a gully on the west side of the tracks, the top of the Jeffersonville limestone is exposed at an elevation of 515 feet A. T.

Section No. 18. A county road crosses the Baltimore and Ohio Railway tracks a few yards north of the above outcrop. This crossing, known as "Gibson's Crossing," is located near the northeast corner of Section 52. About 100 yards north of this crossing, the Baltimore and Ohio Railway again passes through a shallow cut in which seven feet of typical Beechwood limestone is exposed down to the railway ditch. Six to seven feet of New Albany shale and soil overlie the limestone. The elevation on the railroad in this cut is 530 ft. A. T.

Section No. 19. Northwest from "Gibson's Crossing," along the county road, near the center of the east line of Section 70, the following section is exposed on the west side of the road in the barn lot of Mr. Glenn Pass:

Beechwood limestone	5 ft. plus, up to roadway
Silver Creek limestone	3 ft.
Covered below	

Elevation on top of the Beechwood limestone..........533 ft. A. T.

The Jeffersonville limestone outcrops in a small gully about 200 ft. west of Mr. Pass' house.

Section No. 20. A mile northwest of Mr. Pass' farm, the county road crosses Pleasant Run by means of a steel bridge. Three hundred feet west of and downstream from the bridge, four feet or more of Louisville (Silurian) limestone outcrop along the stream at an elevation of 462 feet A. T. This outcrop of Silurian has been traced by the writers for a distance of over a mile upstream and approximately a half-mile downstream from this point. The inlier of Silurian is considerably west of any previously reported inliers and is probably caused by Pleasant Run cutting across a structurally high point. As will be shown in connection with the structural map which accompanies this paper, this inlier is situated upon a structural terrace.

The section above the Silurian limestone is covered for eight feet, but above that, Jeffersonville limestone forms the north bank of Pleasant Run with 15 feet of cherty soil capping the limestone. The thickness of the Jeffersonville limestone was measured as 37.5 ft.

Elevation on top of the Jeffersonville limestone......508 feet A. T.

Section No. 21. About a mile southwest of Section No. 20, another county road crosses Pleasant Run near the middle of the west line of Section 70. The following connected section was obtained along the road, north of the stream:

Red clay soil with chert	10	ft.
Silver Creek limestone with some chert nodules	4	ft.
Covered	3	ft.
Silver Creek limestone, typical; *Chonetes yandellanus* abundant	2	ft.
Covered	2	ft.
Jeffersonville limestone, white, crystalline; partly covered to creek bed	28½	ft.
Jeffersonville limestone, brown, very coralliferous	1	ft. in creek bed

West of Charlestown

Section No. 22. About a half-mile northwest of the bridge mentioned in Section No. 18 is a road intersection located at the junction of Sections 113, 114, 92 and 93. Eight hundred feet southwest of this intersection, in the northeast corner of the northwest quarter of the northeast quarter of Section 92, the following connected section was obtained:

New Albany shale and soil	8 to 10 ft. plus
Silver Creek limestone (partly covered)	16½ ft.
Jeffersonville limestone	18 ft.

The lower eight feet of the Jeffersonville limestone of the section is exposed in a spring 50 feet south of the road. No Beechwood limestone was found.

Two hundred yards north of the road, fifteen feet of Silver Creek and the top of the Jeffersonville limestones are exposed.

Elevation on top of the Silver Creek limestone.........534 ft. A. T.

Section No. 23. Northeast of the road intersection, in the northeast quarter of the southwest quarter of Section 114, on the farm of Mr. John Peyton, about 200 yards north of the barn, the following section was obtained.

Soil containing an extreme abundance of chert (New Chapel bed?)	5 ft. plus
Silver Creek limestone; typical fine-grained limestone	5 ft.
Jeffersonville limestone (partly covered)	15 ft.

Just east of Mr. Peyton's house is located a spring house. The water issues from a joint crevice near the top of the Jeffersonville limestone. The crevice is three to four feet wide and about eight feet high.

The Jeffersonville limestone is very fossiliferous at this point.

Section No. 24. Northeast, toward Charlestown, the road crosses Pleasant Run in the northeast quarter of Section 93. A connected section measured along the road from stream level to near the top of the south wall of the valley is as follows:

New Albany shale and soil	17 ft.
Covered terrace	20 ft.
Jeffersonville limestone	47 ft.
Louisville limestone (Silurian)	2 ft.

Elevation on top of the Jeffersonville limestone......522 ft. A. T.
Elevation on top of the Louisville limestone...........475 ft. A. T.

The Silurian limestone exposed in the stream bed of this section is a continuation of the Silurian exposure described in Section No. 18. The easternmost limit of this inlier was found about 250 yards upstream from the point where the road crosses Pleasant Run.

The Jeffersonville limestone is abnormally thick in this area.

Section No. 25. North of the above section, near the center of the northwest quarter of Section 115, on the farm of Edward Brocklehurst, is a small abandoned quarry which exposes thirteen feet of Silver Creek and six feet of Jeffersonville limestones. The ten feet of soil above the Silver Creek limestone contains chert and an abundance of black, water-worn pebbles similar to those found in the basal conglomerate of the Beechwood limestone.

The quarry is located about 300 yards south of Mr. Brocklehurst's house. A small stream which flows past the quarry exposes most of the Jeffersonville limestone.

Section No. 26. West of the Brocklehurst quarry, near the center of the north line of the northwest quarter of Section 114, is a roadside outcrop of five feet of Beechwood limestone. The elevation on top of this outcrop is 518 feet A. T.

Six hundred feet south of the Beechwood outcrop, in a pasture on the farm of William Martin, is a small swallow hole entrance to a cave in the Jeffersonville limestone. The cave is situated near the bottom of a small valley and only the upper five to six feet of the Jeffersonville formation are exposed. The elevation on top of this limestone is 499 feet A. T. Only a foot or so of Silver Creek limestone is exposed above the Jeffersonville limestone, but judging from the elevations obtained, the formation is approximately 14 feet thick at this place.

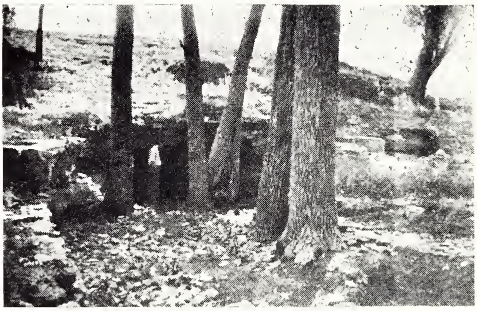

Fig. 6. Entrance to cave in the Jeffersonville limestone on the Herbert Ross farm, about two miles west of Charlestown, Ind. Subterranean drainage is common and caves of considerable size are frequently found in the Jeffersonville formation.

Section No. 27. North and east toward Charlestown, near the middle and just south of the north line of Section 94, a small tributary from the east joins Pleasant Run. A few yards north of the junction of these streams is an excellent exposure of Jeffersonville limestone. The details of this section are as follows:

Slabby weathering, very fossiliferous, gray-brown, crystalline limestone.....	4	ft.
Massive, coarsely crystalline, white limestone	6	ft.
Massive, fine-grained, brownish-gray limestone	3	ft.
Slabby weathering, sub-crystalline to fine-grained, gray to white limestone......	10	ft.
Dark blue-brown coralliferous limestone.	3½	ft.
Total thickness	28½	ft.

There are two caves in the Jeffersonville limestone at this place. (Fig. 6.) The larger of the two caves has an abundance of drip-stone on the walls and roof, but the interior of the cave is dry. The height of the entrance is about six feet. The smaller cave is a few yards south of the dry cave and contains a small spring, but no drip-stone. This cave is only three or four feet in height at the entrance. To the east of the caves are several large sinkholes.

Section No. 28. The county road to Charlestown crosses the above mentioned tributary of Pleasant Run about an eighth of a mile east of the forks of the two streams. The following connected section was obtained along the stream and road at that point:

New Albany shale....................	5 ft. plus
Beechwood limestone	3 to 4 ft.
Silver Creek limestone.................	13 ft.
Jeffersonville limestone	33 ft. to stream bed

Elevation on top of the Beechwood limestone..........552 ft. A. T.

The lowest portion of Jeffersonville limestone exposed in the stream bed is extremely coralliferous and is probably near the base of that formation. The top of this formation contains the usual densely fossiliferous zone in which the fossils are stained a dark purplish red.

The upper part of the Silver Creek limestone is cherty but it was impossible to obtain a definite figure for the thickness of the New Chapel chert bed.

Section No. 29. In the northeast quarter of the northwest quarter of Section 95, the following section is to be seen along the roadside:

New Albany shale....................	3 ft. plus
Beechwood limestone	4 ft.
Covered below	

Elevation on top of the Beechwood limestone..........570 ft. A. T.

Section No. 30. Three hundred yards northeast of the above outcrop, in the northeast quarter of Section 95, four feet of Beechwood limestone outcrop at the side of the road. The elevation on top of the limestone is 574 ft. A. T. Eight hundred feet northeast of this outcrop, across a dip in the road, the same limestone outcrops at an elevation of 584 ft. A. T.

North and Northwest of Charlestown

Section No. 31. Pleasant Run, which flows through the west side of Charlestown, exposes a continuous outcrop of Jeffersonville and Silver Creek limestones extending over a distance of about one mile. The west bank of this small stream offers many sections for detailed study, while the whole series of exposures presents an excellent picture of the Devonian stratigraphy of that immediate area. The two sections below were obtained along Pleasant Run and are representative of the stratigraphy along that stream.

At the west end of Water Street in Charlestown, Pleasant Run swings around the base of "Halcony Hill" and exposes a bluff of Jeffersonville limestone on the west bank. The details of this section are as follows:

Massive, crystalline, gray to yellowish-brown limestone containing crinoids	15 ft.
Thin-bedded, white, crystalline limestone containing *Stropheodonta concava* and many *Fenestellas*	2½ ft.
Massive, white, crystalline limestone	3 ft.
Thin-bedded, brownish, sub-crystalline limestone	2 ft.
Massive, gray, sub-crystalline limestone	3 ft.
Shaly, buff to gray, sub-crystalline limestone	3½ ft.
Massive, buff to gray, crystalline limestone containing *Spirifer gregarius* and many corals	2 ft.

Section No. 32. A paved road runs north from Charlestown and crosses Pleasant Run, by means of a small concrete bridge, an eighth of a mile south of the middle of the north line of Section 117. The following connected section was obtained along Pleasant Run, from the bridge to a point about 800 feet downstream:

Soil	2 ft.
Silver Creek limestone	14 ft.
Jeffersonville limestone	3 ft. plus

The New Chapel chert bed of the Silver Creek limestone is very definite in this section and occupies the upper four feet of the formation. The chert is bedded in a massive, fine-grained gray limestone. Fossils are numerous in this cherty bed.

There is no definite break between the New Chapel chert bed and the lower 10 feet of Silver Creek limestone. The five to six feet of strata immediately below the New Chapel bed are composed of a massive, blue-gray, fine-grained limestone that contains some nodular chert. The next two feet of strata consist of fossiliferous, slabby, crystalline, gray limestone; and the basal two feet of the formation consist of a layer of brown, soft, argillaceous limestone. This basal layer is almost like a shale and fractures into blocky segments similar to some shales.

A few yards north of the bridge at this section, the New Albany shale is found above the Silver Creek limestone but no Beechwood limestone could be found. The Beechwood is evidently thin in this immediate area and obscured by the shale.

Section No. 33. Northwest of Charlestown, on the Henryville road, the following connected section was obtained in the northeast quarter of the northwest quarter of Section 136, along a tributary of Sinking Fork Creek:

New Albany shale	5 ft. plus
Beechwood limestone	3 ft.
Silver Creek limestone	19 ft.
Jeffersonville limestone	1 ft. to stream bed

Elevation on top of the Beechwood limestone..........540 ft. A. T.

The Beechwood limestone in this section is very typical, being a massive, dark gray, coarsely crystalline, very crinoidal, hard limestone. The basal four inches of the Beechwood is composed of a conglomerate of black water-worn pebbles cemented in a matrix of sub-crystalline limestone. The conglomerate lies disconformably upon the New Chapel chert bed of the Silver Creek limestone.

The New Chapel chert bed of the Silver Creek limestone occupies the upper four feet of that formation. The chert occurs in abundance and lies in rather uniform layers. The top of the cherty horizon is very fossiliferous. Fifteen feet of argillaceous, blue-gray, fine-grained limestone lie below the cherty bed. There is some indication of a break between the two parts of the formation. The lower part of the Silver Creek formation contains some irregularly spaced chert nodules but the quantity is small compared with that in the New Chapel bed. The Silver Creek limestone in this section contains an abundance of silicified fossils.

Section No. 34. The Silver Creek limestone outcrops beneath the New Albany shale at an elevation of 528 feet A. T., along the side of the Henryville road, at the center of the north line of Section 154. No Beechwood limestone was observed.

Section No. 35. One-half mile northwest of the above outcrop, along the same road, the Beechwood limestone is found below the New Albany shale at an elevation of 508 feet A. T. The Silver Creek limestone is exposed below. The Beechwood member is partly covered but the maximum thickness probably does not exceed three feet.

Section No. 36. Several sections were obtained west of Charlestown, on the road to Memphis. The first exposure west of the forks of the Memphis-Henryville roads is at the base of a steep hill, near the center of the west line of Section 136. The connected section down this hill is as follows:

New Albany shale....................	88 ft.
Beechwood limestone	3 ft.
Silver Creek limestone................	exposed

Elevation on top of the Beechwood limestone.........533 ft. A. T.

Section No. 37. The Memphis road crosses a small branch of Sinking Fork Creek near the center of the southwest quarter of the northwest quarter of Section 153. The Jeffersonville limestone is exposed in the stream bed. Two hundred and fifty yards east of this crossing, the following section is exposed in the south bank of the stream:

Silver Creek limestone................	14 ft.
Jeffersonville limestone	12 ft.

Elevation on top of the Jeffersonville limestone.......584 ft. A. T.

There is a small cave in the Jeffersonville limestone, about three feet below the top of that formation.

Section No. 38. In the extreme northwest corner of Section 153, the upper four to five feet of Jeffersonville limestone is exposed at the base of a gravelly hill. In a dirt road, a few feet north of the Jeffersonville outcrop, the Silver Creek limestone is exposed to a thickness of 10 feet. Probably a few feet should be added to this latter thickness to obtain the true thickness at this point.

Section No. 39. Near Stony Point church, which is located near the center of the west line of Section 152, three quarries expose the Jeffersonville limestone to a depth of 25 feet. A connected section measured at the quarries and exposures in a field to the north of the church gives the following thicknesses:

New Albany shale....................	— ft.
Beechwood limestone	1 ft.
Silver Creek limestone................	17 ft.
Jeffersonville limestone	25 ft. plus

Elevation on top of the Beechwood limestone..........489 ft. A. T.

Section No. 40. About a mile north of Stony Point church, at the junction of the Charlestown-Memphis road with the Stony Point road, the Beechwood limestone is found below the New Albany shale at an elevation of 477 feet A. T.

Section No. 41. Two hundred and fifty yards northwest of the above road junction, the Silver Creek limestone is exposed on the west side of the road at an elevation of 465 feet A. T. No Beechwood limestone was observed; the New Albany shale apparently rests directly upon the Silver Creek limestone.

Section No. 42. In the northeast quarter of the northeast quarter of Section 133, the top of the Jeffersonville limestone is exposed in a road cut in front of E. Burnes' home. The Silver Creek limestone outcrops at the top of the hill, a few yards south of the house.

Northeast of Jeffersonville

Outcrops of the Devonian limestones are scarce from Jeffersonville eastward along the Ohio River to Utica. The rise from the river northward to the uplands is accomplished over a series of wide terraces composed of Pleistocene sands and gravels; and it is only at points where the larger streams have eroded through the Pleistocene deposits that bed rock is encountered. Two sections were obtained by the writers at points where the uplands merge with the river terraces.

Section No. 43. Near the center of the east line of Section 12, on the Gilmore Dairy Farm, the following section was obtained from an exposure just east of the Gilmore house:

Soil	1 to 2 ft.
Silver Creek limestone................	10 ft.
Jeffersonville limestone	exposed

The New Chapel chert bed of the Silver Creek limestone is four feet in thickness at this point, and is well developed.

Section No. 44. About one mile east of the above section, near the center of Section 14, is a road quarry which exposes the following section:

Cherty soil	1 to 2 ft.
Silver Creek limestone	2 ft.
Jeffersonville limestone	25 ft.

The Jeffersonville limestone is exposed down to the dark brown, basal, coralliferous horizon of that formation.

North of Utica

The Ohio River follows a nearly due south course from Charlestown Landing to the vicinity of the town of Utica. This portion of the Indiana side of the river consists of high river bluffs with a comparatively narrow flood plain; in places there is barely enough room between the valley wall and the river's edge for the highway which parallels the stream. These bluffs, for the most part, are composed of Silurian rocks, and rise as sheer walls which vary from seventy-five to one hundred feet to several hundred feet in height. The base of the bluffs is heavily mantled by talus. The top of the bluffs is capped by several feet of basal Jeffersonville limestone and affords opportunity for collecting the corals which are so abundant in the base of that formation.

At Utica, these bluffs are quite high, but as noted above, from Utica to Jeffersonville, high bluffs are absent on the Indiana side of the river, although there are bluffs on the Kentucky side. This peculiar topographic condition is interesting and deserves further study. The abruptness with which the bluffs terminate at Utica suggests that a former bend of the river might have reduced the bluff between that point and Jeffersonville.

As the Devonian outcrops north of Utica are restricted to the Jeffersonville limestone, little time was spent by the writers in this area. Two sections are worthy of mention, however.

Section No. 45. One mile north of Utica, on the road to Charlestown, in a small quarry in the northwest quarter of the northwest quarter of Section 17, over eight feet of brownish, coralliferous, basal Jeffersonville limestone is exposed. The Louisville (Silurian) limestone is exposed below.

Although no particular study was made of the coralliferous horizon of the Jeffersonville limestone, there is some evidence that the horizon thins towards the west and north. For example, in this section it is over eight feet in thickness while at Speed it is only three feet in thickness.

Section No. 46. At Charlestown Landing, the thickness of the Jeffersonville limestone exposed at the top of the river bluff was determined to be 33 feet. The elevation of the contact of the Louisville and Jeffersonville limestone is 535 ft. A. T. at the side of the road leading up from the river to the top of the bluff.[15]

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[15] For topographic or structural work along the Ohio River in Clark County, the river level furnishes a convenient datum plane. Due to the river dam system, the water level at normal stage is approximately 420 ft. A. T., anywhere between Louisville, Ky., and Madison, Ind. Government engineers use this datum plane in doing flood-control mapping.

STRUCTURAL MAP

Clark County lies on the west flank of the Cincinnati arch. The regional structure has resulted from the deformation of strata during the uplift of the Cincinnati arch. The regional dip of the rocks of the county is, therefore, in a westerly direction. The regional strike of the rocks is approximately north and south.

The structural map which accompanies this paper (Fig. 7) is an attempt to show the structural conditions existing in an area of about 100 square miles in central Clark County. The top of the Silver Creek limestone (including the New Chapel chert bed) was used as a datum in making the structural determinations. In the interpretation of the available structural data, some interpolations were necessary where the key horizon was absent. Much care, however, was necessary in making such interpolations because of local variations in thickness of the key horizon. As has been noted in the detailed stratigraphy above, the upper surface of the Silver Creek formation, apparently, has been eroded in certain areas; and it is necessary, therefore, to be thoroughly familiar with the characteristics of that horizon before attempting any interpolations.

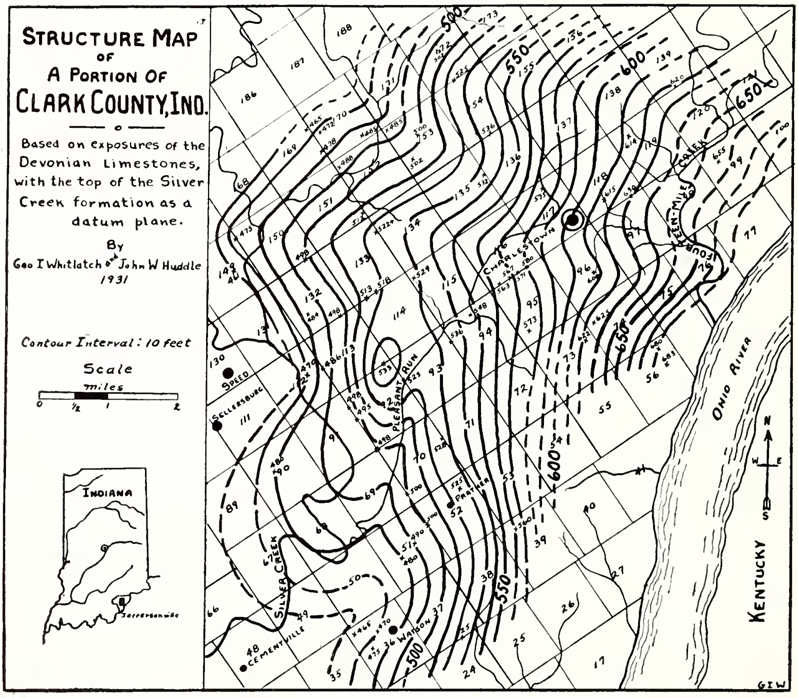

Fig. 7. Map of the eastern and central parts of Clark County, Indiana, showing the structural conditions of that area as determined upon the top of the Silver Creek (Devonian) formation.

The completed map has been checked with other maps prepared from data obtained entirely from the Jeffersonville and the Beechwood horizons and these maps confirm, in all essential respects, the more completely delineated structure obtained by using all available data. This confirmation apparently justifies the use of the top of the Silver Creek limestone as a datum plane for structural mapping, despite any irregularities due to a possible rolling contact of the Silver Creek limestone with the overlying Beechwood limestone.

Two prominent structural features are indicated by the structural map. The first of these is a broad structural terrace or "nose" which extends nearly due west across the entire area. A shallow but very definite syncline bounds this "nose" on the north. To the south, this northern "nose" merges into a second structural terrace which is bounded on the southeast by a narrow syncline. Taken as a unit, the structural terraces form a single compound terrace that is approximately five miles in length and three to four miles in width.

East of the 540-foot contour line, structural irregularities are not very great. For the most part, the dip is in a general westerly direction at about 30 feet to the mile. The strike preserves a general north-south trend. The most pronounced irregularities in this eastern part of the area occor in the vicinity of Charlestown. These irregularities are due principally to the eastern extension of the northern terrace and syncline which bounds it. It is worthy of noting, however, that in the northeastern part of the area the structural lines tend to swing to the east. It is possible that additional structural features exist north and east of the area under discussion.

The structural irregularities become very pronounced west of the 540-foot contour line. It is in this western half of the area that the compound terrace occurs. The northern portion of the terrace is very uniform in outline with no abrupt steepening of dip. The axis of the "nose" of this part of the terrace extends nearly due east and west. The most prominent feature of the "nose" is a flattening of dip south of the axis between the 520 and 530-foot contours. This flatness of dip increases in width towards the south and culminates in parts of Sections 113, 114, 92 and 93, forming the second terrace of the structure.

In this southern part of the structure, the area between the 520 and 530-foot contours in Sections 114, 93, and parts of 92 and 113 is very flat. A possible reversal of dip is indicated by a single elevation of 533 feet A. T. obtained near the intersection of the above four sections. On the basis of that one elevation, a closed contour with a value of 530 feet A. T. was placed on this flat. West of the closed contour, the dip of the limestone steepens very rapidly for a distance of about one-half mile and then tends to flatten out again, so that to the southwest, the dip is only about 10 feet to the mile. This gives rise to a "flat nose" or subordinate terrace of considerable size.

Correlative evidence of the existence of a terrace or other structural high in the region of the interesction of Sections 113, 114, 92 and 93 is seen in the presence of the Silurian inlier in the bed of Pleasant Run, one-half mile to the south. This limestone is considerably west of its normal outcrop and its presence in this area is probably due to the stream cutting down into and across a structural high or terrace, as shown by the map. Further evidence of the flatness of dip in this particular area is shown by two elevations obtained along Pleasant Run at the contact of the Jeffersonville (Devonian) and Louisville (Silurian) limestones. The elevation of that contact in the northeast corner of Section 93 is 475 feet A. T., while an elevation of that contact obtained a mile southwest, near the middle of the west line of the same section is 470 feet A. T., showing a dip of only five feet in that distance.

The syncline which bounds the southern part of the terrace on the southeast has been difficult to delineate for several reasons, among which are: (1) the absence of adequate exposures of the Silver Creek limestone in this immediate area; (2) an abnormal thickness of the Jeffersonville limestone in the vicinity of the syncline; and (3) the unconformable contact of the Devonian and Silurian limestones. All of those factors have been detrimental to accurate delineation of the syncline. The syncline may be deeper than is indicated, but from the structural data available, the syncline is not deeper than shown.

Regionally, the presence of a structural high is clearly indicated on the geological map which accompanies Siebenthal's report on the hydraulic limestone of Clark County. Study of this map combined with a knowledge of the topography of the county is sufficient to show that the width of the Devonian limestones outcrop is too great for the thickness of the combined formations. The Devonian limestones outcrop east of Fourteen Mile Creek and were the dip normal to the west, the width of the outcrop belt would be considerably less than it is from Fourteen Mile Creek through Charlestown to Speed. The structural conditions outlined above have prevented the limestones from dipping under at their normal rate, hence an increased width of outcrop. It was from such reasoning that the writers first suspected the presence of structural irregularities in Clark County.

SUMMARY

The Devonian limestone area studied by the writers in Clark County offers many interesting problems to both the stratigrapher and the paleontologist as well as to the structural geologist. In the above pages the writers have pointed out or have indirectly suggested a few of the outstanding questions connected with the Devonian formations. Lack of time prevented detailed investigations of any of the problems that arose during the course of the summer's work. It is felt, however, that the results accomplished have been worthwhile. Numerous new sections have been listed, several old sections published in earlier reports have been revised; a new inlier of Silurian rock is reported for the first time; the chert bed of the Silver Creek formation is named; and structural conditions in the area are presented by a detailed map.

In regard to the structural conditions, the present work has established the fact that, although there are minor irregularities of structure, the regional dip is, in the main, toward the west. Locally the dip becomes very slight and thus accounts for the unusual width of the Devonian outcrop in this part of Clark County. The regional direction of strike is not influenced greatly by the structural irregularities and is, for the most part, normal, i. e., in a general north-south direction.

THE GENETICS OF IDEAS IN THE REALM OF MATHEMATICAL PHYSICS

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This paper is written in an attempt to describe the mental processes by which a new idea is originated. The attempt to formulate these processes is made by the use of one or more well known analogies. In this way one can express the new idea in terms of old familiar ones. This method of analyzing and solving problems by analogies is used in mathematics and physics quite generally. The idea of expressing an idea in terms of old familiar ones is analogous to defining an unknown quantity in terms of known quantities and is the basis of all logic and mathematics. The new idea is the analogue of the dependent variable and the old familiar ideas are the analogues of the independent variables. However, in this case the familiar ideas need not be independent (unrelated).

The most common case seems to be the one in which there are only two familiar associated ideas and the new one which depends upon them. The two associated familiar ideas correspond to a mathematical function of two independent variables and the new idea corresponds to the dependent variable. All other cases can be reduced to the one just mentioned.

The process by which new ideas are originated seems to be related very closely to processes in the field of genetics. This statement is amplified by the fact that the association of two ideas can result in the suggestion of a new idea. This concept of "a new idea originating from two old ones" is very closely related to the concept of "a child and its two parents." In fact the process by which ideas are originated is analogous to that of "conception and birth" in the case of animals. This brings us to the subject of the paper, namely, "Genetics of Ideas."

If one follows out the analogy as stated, an original idea represents the child of two parent ideas. In order to follow out this analogy and speculate as to how new ideas are originated, it will be necessary to observe some familiar cases of parent ideas and their offspring.

The series of mechanical quantities—mass, displacement and time provide the parent ideas and the series of derived quantities—speed, acceleration, force, work, power, momentum, and action furnish examples of the offspring. The two series are arranged in the following table:

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Parent Ideas		Offspring
Displacement	Time	Speed
Change in speed	Time	Acceleration
Speed	Mass	Momentum
Change in momentum	Time	Force
Momentum	Displacement	Action
Force	Displacement	Work
Work	Time	Power

It has been said that necessity is the mother of invention. In other words, the need for a certain thing impels one to find a way to get it. One knows what he wants before he seeks for it. This is precisely the case in the breeding of stock where parent stock is selected which will produce offspring with the desired characteristics. In carrying out our analogy in this case the invention which necessity has mothered is the offspring with certain desired characteristics. The original idea which we call an invention in this case must be bred from parent ideas which should produce the desired characteristics in their offspring. The following example illustrates this case:

It is necessary to measure the angle of inclination of an inclined plane. Invent an inclinometer. We will select two parent ideas, one of which has the quality of indicating vertical or horizontal lines and the other has the quality of indicating angle. The two ideas are associated in a mental picture with the result that a first suggestion comes to mind of using a spirit level and a protractor in some combination to measure the angle of inclination. Probably after trying the level a second suggestion comes to mind of improving on the level by using a plumb line attached at the center of the protractor. It is seen that the parent ideas, "plumb line" and "protractor" are selected because they should produce an offspring with characteristics common to both. The developed invention is a protractor with a plumb line attached to its center of arc.

In analyzing and solving problems, one generally knows the general characteristics of the answer before hunting for it. The solution of a problem consists of a statement in terms of known quantities. One must find the known quantities which are related to the answer before it can be fully determined. This is like trying to find the parents of a child by knowing its physical characteristics.

Take for example the problem of finding what acceleration a body will have if it were allowed to fall freely at the surface of the moon. We know the general characteristics of the child, and are required to find its two parents. Since we know that force of attraction produces acceleration, and that all bodies attract each other, we can find the identity of the parents through these relations. First, mass times acceleration is a force which is equal to the force of attraction and the force of attraction is proportional to the product of the two masses divided by the square of the distance between them. Hence, gravity is proportional to the ratio of the mass of the moon to the square of its radius. The two parent quantities are therefore the mass of the moon and its radius squared

$$F = M_1 g = G \frac{M_1 M_2}{(r^2)}$$

$$g = G \frac{M_2}{r^2} \quad \text{(G is a proportional factor)}$$

The relation between gravity and the mass of the moon is that the moon attracts a body and produces the acceleration while the relation between gravity and the square of the radius of the moon is that the attracting force is inversely as the square of the distance between the attracting bodies and thus reduces the force and accordingly the acceleration.

Let the Lorentz system of co-ordinate transformations represent the new original idea, then the two parent ideas are first: the idea of a moving reference system having constant velocity, second: the idea that the laws of nature are independent of speed (if constant). When these two ideas were associated mathematically by Einstein, the special theory of relativity was originated. That is to say, the mathematical deductions based upon these ideas gave Lorentz's transformation directly.

If the analogy between breeding animals and originating ideas is carried on logically, it leads to many interesting concepts. The most interesting one is that of conception and birth of ideas. Analogously it is the uniting of the "life cells" of the parent ideas to start the development of the embryo idea. The birth of the new idea consists in the complete statement of it in terms of the known parent idea. Just what the life cells of ideas are and how they can be united to form an embryo idea is an unanswered question. When an original idea is conceived, a person says that he has a "hunch," or a suggestion. But naming a thing does not define it. Perhasp psychology can tell what mental processes go on during the act of associating ideas which will lead to a more rapid breeding of new ideas, or perhaps we might say to a formula for the mass production of them.

In the field of Mathematics and the physical sciences the following generalization or formal method for the analysis and the solution of physical problems has been used with great success. Probably the method is used a great deal without a knowledge of its formulation. First, the problem at hand must be clearly stated so as to know as nearly as possible the characteristics of the desired solution, namely, the unknown quantity or function to be found. Second, quantities or functions must be found which have some relation to the answer, or to each other. These relations are generally known as laws of nature or mathematics. If as many independent relations can be found as there are unknown quantities involved, a solution is possible. Third, as many algebraic equations as there are unknowns must be written, and by eliminating the unknowns, express the answer in terms of the known quantities.

SOME OBSERVATIONS ON THE FORMATION OF STRIAE IN A KUNDT'S TUBE AND ALLIED PHENOMENA

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The facts contained in the following brief historical summary were taken from a paper by Irons.[1]

Kundt,[2] in his original experiments, used a glass tube strewn on the inside with Lycopodium powder. When the tube was properly clamped and stroked with a dampened cloth, the familiar dust figures were formed in the tube. Kundt noticed that, after stroking the tube for some time, circles of powder formed at the nodes on the bottom of the tube. The formation of these circles was attributed in part, at least, to the vibration of the glass tube. In his later experiments he used a glass tube in which the air was disturbed by means of a diaphragm attached to the end of a metal rod,—the form of apparatus commonly used in laboratories today. With this apparatus he observed that on stroking the rod, vertical rings, the planes of which were perpendicular to the axis of the tube, were formed above dust heaps on the bottom of the tube at the nodal points of the air column. Sand and iron filings also were used in the tube. The important conclusion at which he arrived was the fact that, regardless of the shape of the dust figures, the half-wave length of the sand distribution in the tube remained constant.

Dvorak,[3] [4] experimenting with water in the bottom of a Kundt's tube, showed that, on stroking the rod, a wall of water was formed across the tube at the antinodes. Also he found that a positive pressure existed at the nodes, and that the air in the sounding tube flowed from a node to an antinode along the center of the tube, and from an antinode to a node along the wall of the tube. This latter fact was later demonstrated mathematically by Lord Rayleigh.[5]

Konig[6] gave an explanation for the formation of striae in a Kundt's tube based on the hydrodynamical equations of Kirchhoff.[7] Konig showed that, having given two spheres of radii R_1 and R_2 separated by a distance r_0 in a vibrating perfect fluid, the components of the forces between them were given by

$$X = -(3/2\pi\rho R_1^3 R_2^3 \omega_0^2 / r_0^4) \sin\theta\,(1-5\cos^2\theta),$$
$$Z = -(3/2\pi\rho R_1^3 R_2^3 \omega_0^2 / r_0^4) \cos\theta\,(3-5\cos^2\theta).$$

where ω_0 represents the velocity of the fluid stream taken parallel to the axis of z, θ is the angle which the line of centers of the spheres

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[1] Irons, E. J., Phil. Mag., **7**:523. 1929.

[2] Kundt. Pogg. Ann. **127**:497. 1866.

[3] Dvorak, Pogg. Ann. **153**:102. 1874.

[4] Dvorak, Pogg. Ann. **158**:42. 1876.

[5] Rayleigh, Phil. Trans. **175**: Part I. P. 1. 1884.
Scient. Papers, **2** p. 239.
"Sound," **2** p. 333. 1926.

[6] Konig, Wied. Ann. **42**:353, 549. 1891.

[7] Kirchhoff, Mechanik, 18 and 19 Vorlesungen, or Robinson, Phil. Mag. **19**:476. 1910.

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

makes with the z-axis, and ρ is the density of the medium. The motion was considered as taking place in the xz plane which included the bottom of the tube. Konig considered $Y = O$, and then when $\theta = n$, where n is an integer,

$$X = 0. \quad Z = 3/2\pi\rho R_1^3 R_2^3 \omega_0^2 / r_0^4,$$
and when $\theta = n/2$,
$$X = -3/2\pi\rho R_1^3 R_2^3 \omega_0^2 / r_0^4, \text{ and } Z = 0.$$

An interpretation of these equations showed that spheres situated in a line parallel to the axis of the tube, i. e., along the direction of sound propagation, repel each other, while spheres situated along lines perpendicular to its direction attract each other. From these facts an explanation of the formation of striae was suggested.

Cook[8 9] proceeded to test Konig's formulae experimentally and found that,—

(a) When particles were not more than half their diameter apart and had their line of centers at right angles to the air flow, they were maintained in equilibrium. (According to Konig's theory the spheres should be in contact.)

(b) Particles having their line of centers along the air flow and within half of their own diameter, approached each other, formed a system like a Rayleigh disk, and rotated into a plane perpendicular to the line of air flow.

During the past seven years the author of the present paper has been experimenting on striae in a Kundt's tube and on allied phenomena in an attempt to obtain an explanation of the formation of these striae. Incidental to the study proper of striae, a study of a solid glass rod, rectangular in cross-section, was made utilizing the discovery of Biot[10] In this study a series of photographs was made revealing clearly the fact that the strain, in a glass rod clamped midway between its ends and stroked at one end with a dampened cloth, increases from the free end, an antinodal point, towards the center, a nodal point. This was shown by the increase in the blackening of the photographic negative by light passing through the rod and through crossed Nicols as exposures were made at regular intervals along the rod. In a similar manner Kundt[11] has shown that striae exist in a glass rod while it is being stroked.

Furthermore, in connection with the study of a glass rod during the summer of 1925, the author found that when a glass rod was clamped midway between its ends, and on the antinodal portion of which some alcohol had been placed, that when the rod was stroked by a cloth dampened with alcohol, alcohol striae formed on the surface of the rod.

It was found by the author[12] that pith dust, formed by grinding

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[8] S. R. Cook, Phil. Mag. 3:471. 1902.

[9] S. R. Cook, Phil. Mag. 6:424. 1903.

[10] Biot, Physique. 2:15. 1828.

[11] Kundt, Winkelmann's "Handbuch", ii. Akustik, p. 324 (1909).

[12] R. V. Cook, Science, 64:404. 1926.
Nature, 118:157. 1926.
Sch. Sc. & Math. 26:722. 1926.

pith from the stalks of sunflower on a fine-grained emery wheel, gave a very light powder found excellent for forming striae in a Kundt's tube. By a method described in the paper above cited, this pith dust was used to produce striae, practically one particle thick, and extending completely across the glass tube. Disks of cork were formed by Abbott[13] with a different arrangement of apparatus.

Striae[14] were formed in a glass tube in which the air column was set into vibration by means of an interrupted air jet, the frequency of which was too low to produce an audible tone.

In order to determine whether or not the striae in a Kundt's tube were due to the vibration of the tube itself, a tube of the form shown in Fig. 1 was used. The tube contained pith dust equally distributed inside it, and it was clamped midway between its ends. The end of the tube was stroked with a cloth moistened with alcohol. When air was present in the tube, very regular striae were formed. When the tube was evacuated, no striae formed, and the pith dust exhibited only a very slight motion at most. This showed that the presence of a fluid was essential to the formation of striae in a Kundt's tube.

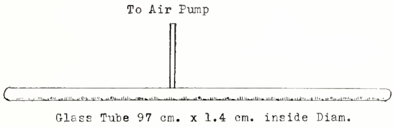

Figure 1.

A photographic study of striae was made by the author using a standard motion picture camera. The photograph and diagram of the apparatus used are shown in Plate I and Fig. 2. A glass tube 1 meter long and about 1.8 centimeters inside diameter had some cork charcoal scattered along its inside and a sheet-tin piston connected by means of a copper wire to one prong of an electrically-driven tuning fork was used to excite the air vibrations in the tube. The piston was inserted a short distance into the end of the tube and the other end of the tube was closed with a tight fitting cork. When the fork was made to vibrate, complete disks of cork dust were produced across the tube at the antinodes and for a considerable distance on either side of the antinodal point. Close observation showed that at each disk two adjacent orbits of rotating particles were present, one on each side of a single striation, one clockwise, and on the opposite side a counter-clockwise rotation. Positives made from a portion of the motion picture negative are shown in Plate II.

Figs. 1(a) and 1(b), Plate III, show enlarged photographs of two such striae. The approximately circular motions take place so that the particles leave the top of the striation and enter at the bottom of the same striation. Midway between two adjacent striae little striae lower than the others tend to form but are soon destroyed by the motions mentioned above, the dust particles forming these lower striae being pulled away in opposite directions and forced into the two adjacent striae at the bottoms of the same. Thus the dust particles are pulled away from a line approximately midway between adjacent striae in opposite directions and forced into the major striae at their bottom portions. Fig. 1(c), Plate III, shows diagrammatically the approximate motion between adjacent striae. When the agitation of the dust particles is violent, the striae at the antinodes, especially those extending completely across the tube as disks, do not remain always in one position, but very often they merge into each other. On two or three occasions it was observed that, when the amplitude of vibration of the tuning fork was diminished slightly by touching the prong of the fork with the finger, a large circular disk on settling down to a striation of smaller

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[13] R. B. Abbott, Purdue University.

[14] Rolla V. Cook, Phys. Rev., **36**:1098-1099. 1930.

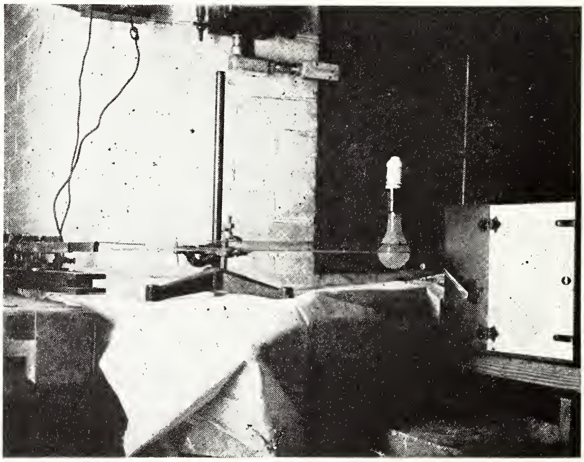


Plate I.

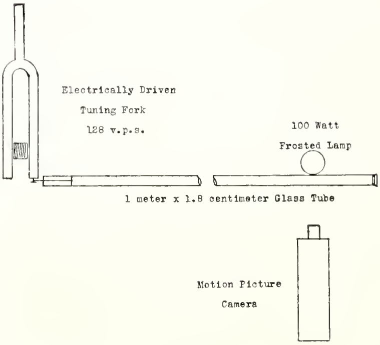


Figure 2.

height, would break up into very thin striations, separated by a distance of one millimeter or less.

In the summer of 1927 the author succeeded in maintaining two paper segments cut in a shape similar to a dust striation, upright in a Kundt's tube. When pith dust also was present in the tube, a violent, somewhat elliptically-shaped rotation about an inch long along its major axis parallel to the axis of the tube, was produced. Also a single segment of paper similar to a dust striation has been maintained upright in the tube for a short time by means of the air vibrations.

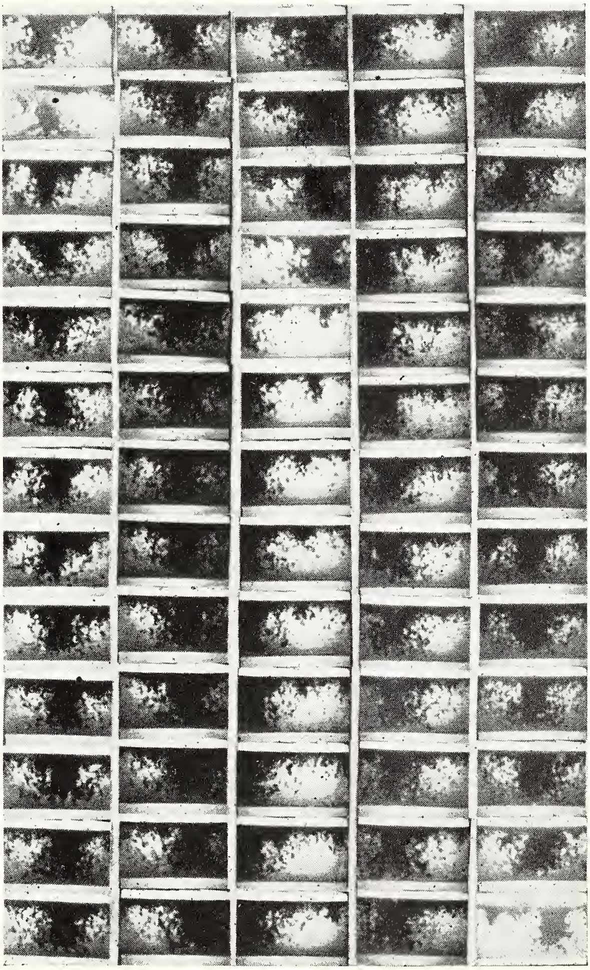
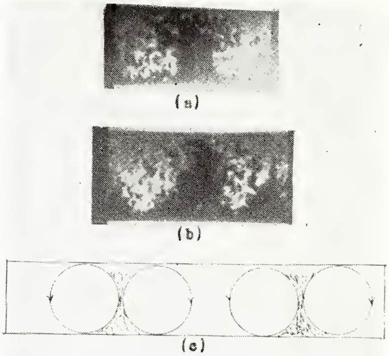


Plate II.

The striae in a Kundt's tube are formed by air vortices in the same manner as ripple-marks in sand are formed by water vortices. As shown by Darwin,[15] these rotations are produced when an alternating fluid flow takes place about obstacles in its path. The clockwise and counterclockwise rotations are maintained always in their respective directions regardless of the fact that the fluid stream is alternating. Fig. 3, (a), (b), and (c) sketched from Darwin's paper shows the directions of rotation of the vortices above sand and adjacent to the two sides of a striation during one-half of a complete oscillation of the fluid stream. The respective directions of rotation remain the same for the second half of the complete oscillation. These vortices are probably originally formed by existing superficial inequalities in the level of the layer of dust particles on the bottom of the tube, or by those superficialities formed by shifting dust particles soon after the air in the tube is set into vibration.

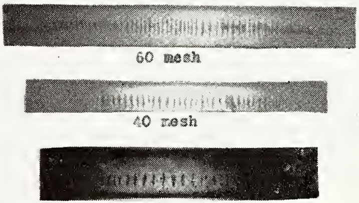


(a)

(b)

(c)

Fig. 1



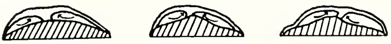
60 mesh

40 mesh

30 mesh

Fig.2

Plate III.



(a) (b) (c)

Figure 3.

A study of the distances between adjacent striae for constant dust particle size and various frequencies was made by means of the apparatus shown in Fig. 4. The data obtained is given in Table I. The air vibration in the glass tube was produced by means of a cork stopper fitted into the cone of a loud speaker unit which, in turn, was driven by means of amplified electrical impulses obtained by means of an electrical pick-up from Fletcher's[16] standard frequency phonograph records. It was found that, as frequency of air vibration increased, the average distance between adjacent striae became smaller. Plate IV shows enlarged photographs of the striae obtained. The frequency markings are relative values rather than absolute values since the speed of the phonograph was not corrected in order to obtain absolute values.

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[15] G. H. Darwin, Proc. Royal Soc., 36:18. 1883.

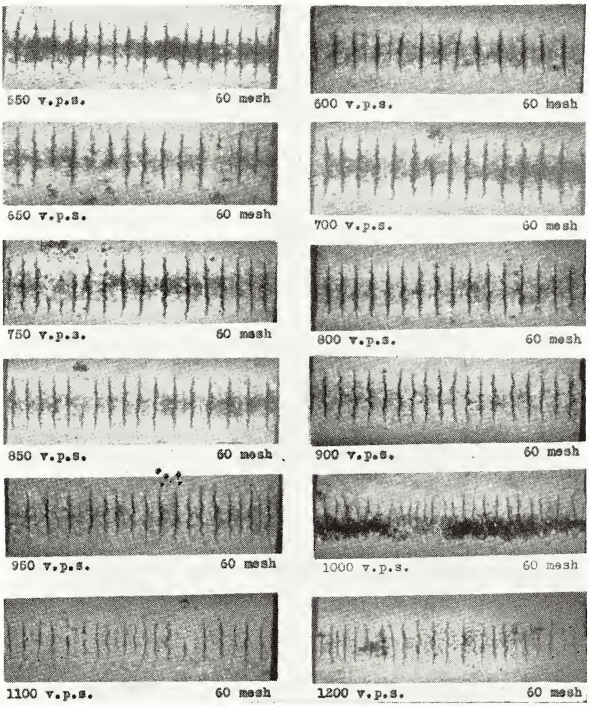
550 v.p.s. 60 mesh
600 v.p.s. 60 hesh
650 v.p.s. 60 mesh
700 v.p.s. 60 mesh
750 v.p.s. 60 mesh
800 v.p.s. 60 mesh
850 v.p.s. 60 mesh
900 v.p.s. 60 mesh
950 v.p.s. 60 mesh
1000 v.p.s. 60 mesh
1100 v.p.s. 60 mesh
1200 v.p.s. 60 mesh

Plate IV.

A study of the distances between adjacent striae for constant frequency and various dust particle sizes was made by means of apparatus very similar to that shown in Fig. 4. The air vibration in the glass tube was produced by stroking a brass rod, (the usual Kundt's method). The photographs of the striae produced, Fig. 2, Plate III, show the striae distances somewhat reduced in size. Table II and Table III give the data taken. Measurements showed that, with a constant frequency of air vibration, the average distance between adjacent striae decreased with decrease in particle size.

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[16] Harvey Fletcher, Bell Telephone Laboratories.

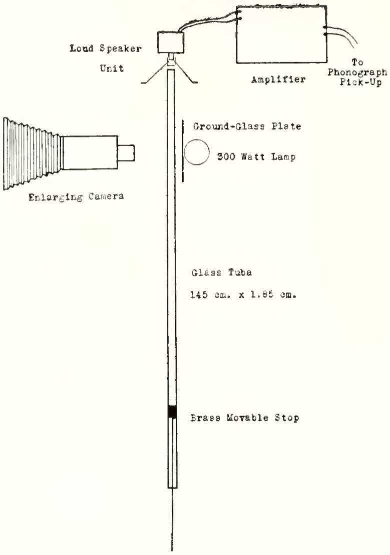

Figure 4.

TABLE I

V. p. s.	No. Spaces	in Length	Average Distance Between Adj. Striae
550.	16.	8.11 cm.	.5 cm.
600.	14.	8.0 cm.	.56 cm.
650.	13.	7.7 cm.	.54 cm.
700.	13.	7.5 cm.	.57 cm.
750.	16.	8.1 cm.	.50 cm.
800.	16.	8.15 cm.	.50 cm.
850.	16.	8.15 cm.	.50 cm.
900.	17.	7.9 cm.	.47 cm.
950.	19.	8.05 cm.	.42 cm.
1000.	23.	8.0 cm.	.30 cm.
1100.	23.	8.0 cm.	.30 cm.
1200.	24.	8.1 cm.	.34— cm.

Particles used = cork particles which passed through a wire sieve having 60 mesh per inch.
Room Temperature, 25°C.
Average Speed of Phonograph Record = 75.25 r.p.m.
Length of Glass Tube = 145 cm.
Diameter of Glass Tube = 1.85 cm.

TABLE II

Cork Dust Mesh/Inch	No. Striae	in Length	Distance Between Striae	Average
30.	31.	7.9 cm.	.25 cm.	
30.	32.	8.0 cm.	.25 cm.	
30.	41.	13.1 cm.	.32 cm.	.308 cm.
30.	40.	13.1 cm.	.33 cm.	
30.	34.	11.6 cm.	.34 cm.	
30.	32.	11.5 cm.	.36 cm.	
40.	59.	12.2 cm.	.20 cm.	
40.	52.	11.5 cm.	.22 cm.	.21 cm.
40.	53.	11.6 cm.	.22 cm.	
40.	61.	12.7 cm.	.20 cm.	
60.	87.	14.1 cm.	.16 cm.	
60.	84.	14.0 cm.	.17-cm.	
60.	74.	12.5 cm.	.17-cm.	.17 cm.
60.	81.	14.0 cm.	.17 cm.	
60.	80.	14.1 cm.	.18 cm.	

Length of Brass Rod = 182.9 cm to disk.
Diameter of Brass Rod = 8.0 mm.
Temperature of Room = 29°C.

TABLE III

Cork Dust Mesh/Inch	No. Striae	in Length	Distance Between Striae	Average
30.	42.	12.5 cm.	.30 cm.	
30.	42.	12.5 cm.	.30 cm.	.30 cm.
30.	36.	11.3 cm.	.31 cm.	
30.	36.	10.0 cm.	.30 cm.	
40.	58.	13.5 cm.	.23 cm.	
40.	49.	11.0 cm.	.22 cm.	.217 cm.
40.	62.	12.8 cm.	.20 cm.	
40.	60.	13.2 cm.	.22 cm.	
60.	63.	11.4 cm.	.18 cm.	
60.	66.	11.5 cm.	.174 cm.	.177 cm.
60.	63.	11.5 cm.	.182 cm.	
60.	67.	11.5 cm.	.172 cm.	

Length of Brass Rod = 182.9 cm. to disk.
Diameter of Brass Rod = 8.0 mm.
Temperature of Room = 35°.5 C.

Summary. The author has shown by the experimental work described in this paper that,—

(a) The strain produced by stroking a glass rod clamped midway between its ends, increases from the antinodal point to the nodal point in the rod.

(b) Liquid striae were formed on the antinodal portion of a glass rod clamped midway between its ends, and stroked with a dampened cloth.

(c) Striae were formed in a glass tube by means of air vibrations, the frequency of which was too low to produce an audible tone.

(d) The presence of a fluid in a Kundt's tube is essential to the formation of striae.

(e) The formation of striae in a Kundt's tube is accompanied by vortices adjacent to the opposite sides of each striation. Such vortices form the striae.

(f) Paper segments similar in shape to a dust striation were maintained upright in a Kundt's tube by means of the vibrating air column.

(g) Using a given dust particle size, increase in frequency of air vibration produces a decrease in distance between adjacent striae.

(h) Using a constant frequency of air vibration, a decrease in dust particle size decreases the distance between adjacent striae.

In conclusion the author wishes to thank Dr. A. L. Foley, Dr. Mason E. Hufford, Dr. J. B. Dutcher, and Dr. R. R. Ramsey for their helpful suggestions from time to time during the progress of the present research which was carried on at Indiana University. The author wishes to thank Assistant Mechanician Mr. Henry Corr and Mechanician Mr. John P. Foley for their assistance in the construction and assembly of apparatus. Also the author's thanks go to Mrs. Anna L. Coleman for secretarial assistance.

THE OWEN BRIDGE FOR INDUCTANCE MEASUREMENT

J. B. HERSHMAN, Indiana University

Many types of bridge circuits have been proposed for the measurement of inductance. The circuits may use direct or alternating current or both. Over a period of a few years the author has tried many of the well known bridge circuits such as those of Anderson, Maxwell, Rosa and Grover, Rimington, Carey and Foster, and others. These circuits will all give good results under certain conditions which are not always obtainable with the equipment at hand.

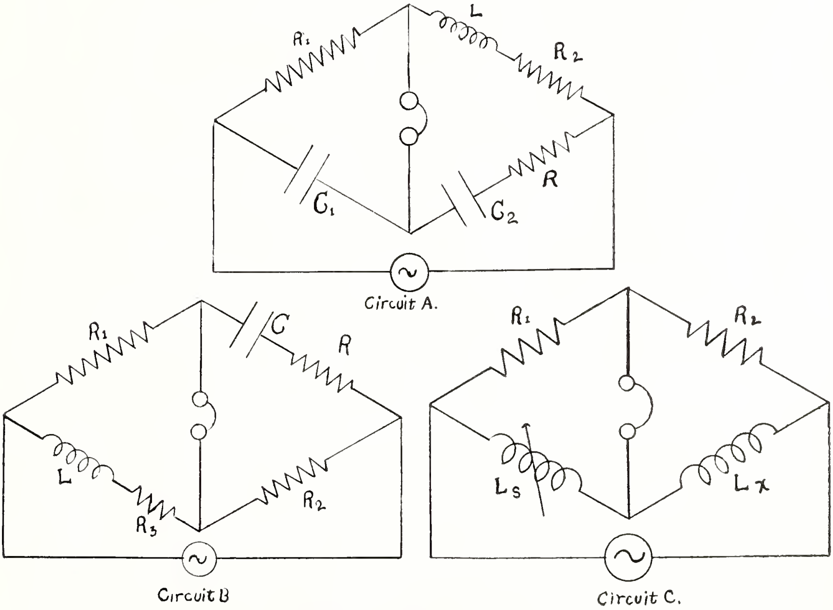

Figure 1. Bridge Circuits.

An alternating current bridge suited to ordinary laboratory apparatus should be independent of wave form, should give accurate results, and should cover a range from one microhenry to thirty henries. It would be desirable to eliminate a direct current balance necessitating galvanometer balancing. The source of current should be inexpensive and the detector of balance a pair of head phones. The standards should be those available in most college measurements laboratories.

Such a bridge was first described by David Owen in the "Proceedings of the Royal Society of London", volume 27, page 39. There seems to be no reference in American texts on electrical measurements to this

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

circuit, although Starling,[1] Moullin[2] and Stanley[3] of England refer to its application.

In figure 1 is represented three alternating current bridges for purposes of comparison. Circuit A is the Owen circuit, circuit B is a modified Owen circuit for measuring coils in which the resistance is small in comparison to the reactance, circuit C is the typical inductance bridge for comparing the unkown inductance to a standard inductometer.

In circuit A, figure 1, L is the inductance to be measured, R_1 may be a known fixed or variable resistor from 1 to 1000 ohms, depending upon the range desired in measurements (small values of L require small values of R). R_2 is a variable resistance (0-2000 ohms) the value of which need not be known. C is a fixed or variable standard condenser. (For small values of L a variable air standard can be used). C_2 is a fixed condenser preferably mica insulated .1 - .5 mfd. capacity—value need not be known.

The source may be any type of audio oscillator[4] or high frequency buzzer with a telephone transformer to couple the buzzer circuit to the bridge. The detector may be a 2000 ohm headphone.

The equations of such a bridge can be derived as follows:

Referring to figure 1, circuit A

$$R_1I_1 = \frac{-jI_2}{\omega C_1} \tag{1}$$

$$(R_2 + j\omega L)I_1 = (R - \frac{j}{\omega C_2})I_2 \tag{2}$$

Dividing (1) by (2)

$$\frac{R_1}{R_2 + j\omega L} = \frac{-j/\omega C_1}{R - j/\omega C_2} \tag{3}$$

Expanding

$$R_1R - \frac{R_1j}{\omega C_2} = \frac{-R_2j}{\omega C_1} + \frac{\omega L}{\omega C_1} \tag{4}$$

Equating reals and imaginaries

$$R_1R = \frac{L}{C_1} \text{ or } L = R_1RC_1 \tag{5}$$

$$\frac{-R_1j}{\omega C_2} = \frac{-R_2j}{\omega C_1} \text{ or } R_1C_1 = R_2C_2 \tag{6}$$

By alternate adjustment of R and R_2 equations (5) and (6) may be satisfied and the bridge balanced.

The accuracy of balance and consequently the accuracy of the measurement depends upon obtaining complete silence in the telephones. Hearing, being a logarithmic function as to judgment of intensity, only by reducing "background" noise can small changes in balance be obtained. A one ohm change in R can easily be detected.

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[1] Starling, S. G., Electricity and Magnetism, 5th Ed. p. 376.

[2] Moullin, E. B., Radio Frequency Measurements.

[3] Stanley, R., Wireless Telegraphy, Vol. I, p. 420.

[4] An Audio Frequency Laboratory Oscillator. Proc. Ind. Acad. Sci. **40**:267-269.

In the tables are some examples of measurements made with this bridge. Table I represents measurements made upon a 1500 turn honeycomb coil and upon a standard inductance of .030 and .040 henries.

TABLE I. INDUCTANCE VALUES FOR VARIOUS COILS

$L = .030$

C_1	C_2	R	R_1	L	R_2
.5	.02	1490	1000	.0298	26
.5	.05	6000	1000	.0300	90
.5	.08	370	1000	.0296	150
.2	.08	370	1000	.0296	390
.2	.08	3700	100	.02960	24
.2	.06	493	1000	.02958	287
.2	.07	423	1000	.02961	337
			$L = .040$		
.2	.08	500	1000	.0400	383
.2	.05	800	1000	.0400	232
.2	.20	202	1000	.0402	
.2	.4	100	1000	.0400	1986
.2	.4	300	333	.03996	
		1500 Turn H. C. Coil			
.2	.236	670	1000	.15812	
.2	.240	658	1000	.15782	
.2	.250	631	1000	.15775	
.2	.560	282	1000	.15790	
.2	.560	941	300	.15808	
.2	.500	1056	300	.15840	

Table II shows the range of inductance values that may be easily covered.

TABLE II. EXAMPLES OF OWEN BRIDGE FLEXIBILITY.

Magnavox output transformer	Henrys
Primary	4.88
Secondary	.009588
60 Turn Solenoid (4" diameter)	Microhenries
Bridge (average)	465
Calculated	465
Wavemeter 1000 K.C.	474
10 Turn Solenoid (4" diameter)	Microhenries
Bridge (average)	21.1
Calculated	21.3
Wavemeter (average)	21.7

If desirable a 1000 cycle audio frequency oscillator may be amplified by a two stage vacuum tube amplifyer and the output used as a source for the bridge. If a vacuum tube voltmeter or rectifying tube is used as a detector, by the deflection of the galvanometer in the plate circuit of such a tube the balanced condition of the bridge may be made. This arrangement gives a visual balance and can be used in noisy rooms with quite a degree of accuracy.

By using a known value for L, C_1 can be found from the formula $C_1 = L/RR_1$.

HIGH VACUUM AND ELECTRODELESS DISCHARGE TECHNIQUE

CHAS. T. KNIPP, University of Illinois

Lecture-demonstrations before Demonstrations and Exhibit Division.

1. Molecular bombardment
2. Production of a vacuum by cooled charcoal
3. Electrodeless ring discharge in bulbs containing various gases
4. Electrodeless discharge—the *flash* in the *afterglow* in certain gases
5. Electrodeless discharge—the *afterglow* in nitrogen
6. Electrodeless discharge—measurement of the *gaseous* current by *its inductive* effect

COMMENT ON THE ABOVE LIST OF DEMONSTRATIONS

Demonstration 1. The underlying principle of the mercury vapor pump may be visualized by a molecular bombardment apparatus (original with Knipp) in which the air molecules are replaced by pith balls which in turn are bombarded and held suspended by the mercury molecules issuing from the heated mercury. The tube is about 1 meter in length and 70 mm in diameter. It contains about 20 cc of mercury, and 2 dozen pith balls. It is thoroughly pumped out and then sealed off. The tube is mounted in a vertical position and the lower end is heated either electrically or by a small Bunsen flame. As the mercury vapor is given off the balls begin to be agitated and with increased heating may be lifted free of the mercury surface and ultimately held dancing in any part of the tube that may be desired. The condensed mercury vapor trickles down the walls of the tube.

Demonstration 2. The absorption of air by cooled cocoanut charcoal is shown simultaneously by an electrodeless discharge in a 500 cc bulb and by the height to which mercury is raised in an attached tube forming a barometric column. This experiment simply illustrates in a striking way what is common knowledge to chemists and physicists—the wonderful absorption and adsorption of gases by cooled charcoal.

Demonstration 3. Electrodeless discharges are not new. Sir J. J. Thomson studied them as far back as 1891. The successful operation of these discharges requires that the bulb (which has no electrodes) be exhausted to a pressure of about .1 mm of mercury. The bulb may be sealed off from the pump. To produce the discharge a high-potential high-frequency generating outfit is necessary. This may be obtained from a 110 volt A.C. lighting circuit by using a transformer and kenotrons; or by a transformer, capacity and a spark-gap. The latter is used in these demonstrations. Bulbs containing various gases (helium, argon,

"Proc. Ind. Acad. Sci., vol. 41, 1931 (1932)."

hydrogen, neon, etc.) are made to glow giving out their characteristic color by inserting the bulb in the energizing coil.

Demonstration 4. A few gases have the property of glowing for some moments after the energizing current is removed. This afterglow seems to be due in part to a molecular rearrangement. The glow dies off exponentially with time. Under certain conditions depending on the kind of gas (argon works best), the moisture and impurities present, there appears early in the decay of the afterglow a sudden flash (new, just recently observed by Knipp) of the illumination that is visible throughout the room. The experiment is striking.

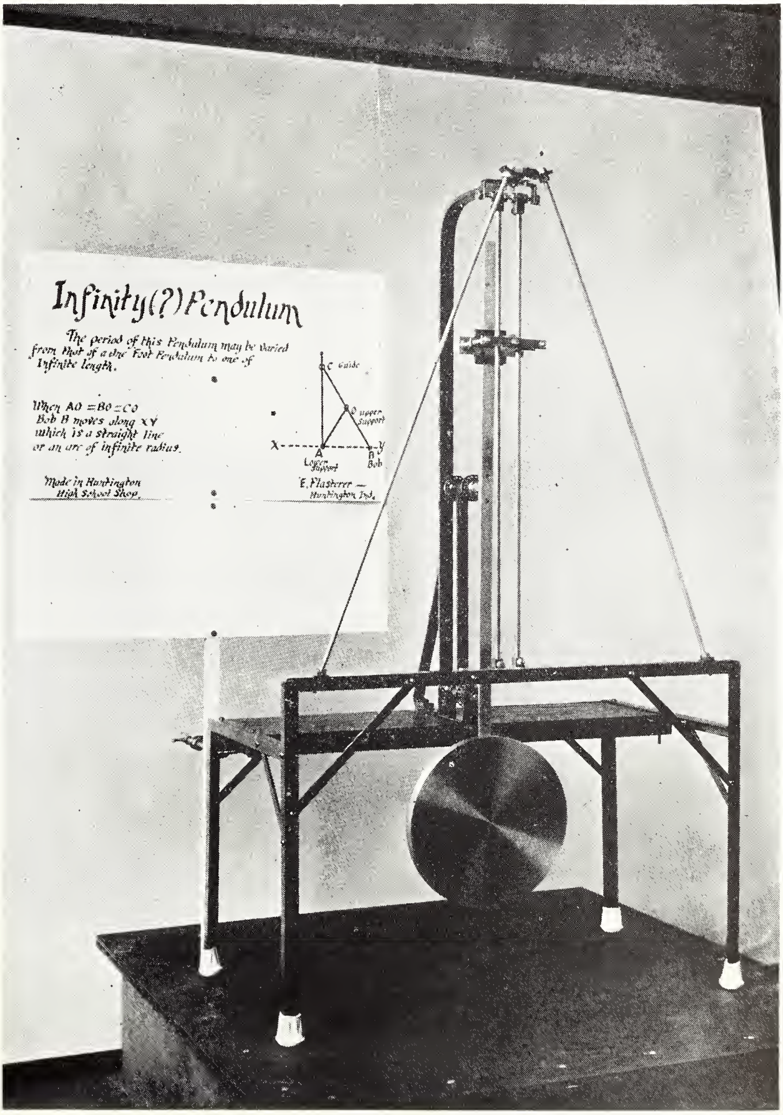
Demonstration 5. It has been known for some time that an electric discharge in nitrogent causes an afterglow to be set up which persists for some time after the exciting coil is removed. Afterglows lasting 15 to 20 minutes have been reported. In this particular bulb the glow lasts for some 35 minutes. A nitrogen bulb that glowed for 187 minutes was reported by Knipp (abstract No. 21) at the recent (Nov., 1931) Chicago meeting of the American Physical Society. The active nitrogen afterglow is a beautiful lemon color.

Demonstration 6. The induced gaseous current in an electrodeless ring discharge may rise to a high value. The magnitude of this current was measured recently by its inductive effect. In the ordinary form of bulb this could not be done by reason of the larger inductive effect of the current in the energizing coil. This was overcome by piping, as it were, the gaseous current aside to a position where this disturbing effect is zero, and then utilizing the *inductive effect* of the *gaseous current* on a metallic secondary connected to a radio-frequency ammeter. See Physical Review, Vol. 38, No. 5, Sept. 1931.

AN INFINITY PENDULUM

E. G. PLASTERER, Huntington High School

The period of vibration of the ordinary physical pendulum is varied by changing the length of the pendulum. The range of length (as gen-


Infinity(?) Pendulum
The period of this Pendulum may be varied from that of a one Foot Pendulum to one of Infinite length.
When AO = BO = CO Bob B moves along XY which is a straight line or an arc of infinite radius.
Made in Huntington High School Shop.
C Guide
O upper Support
X
Y
A
Lower Support
B
Bob
E. Plasterer — Huntington Ind.

erally demonstrated) varies from about zero to ten feet or more depending on the convenience of locating the center of suspension. While the period of the ordinary pendulum is thus limited by physical limitations of length the infinity pendulum has no such limitations. There are no limitations because the center of suspension is theoretical and not material.

The hypothetical length can be changed by a slide adjustment from that of a few inches to one of infinite length.

The "Infinity Pendulum" (if I may name it thus) is a device by which a weight or bob is caused by gravity to vibrate through arcs having radii of any length. The bob vibrates below a vibrating support of the same period, however the degree of the vibration of the support is determined by the position of a wheel and clamp on the pendulum bar. The wheel and clamp is free to vibrate only in a vertical sense.

The accompanying photograph shows the details of the apparatus and also a diagram of the one case in which the pendulum has an infinite length. By the plane geometry indicated it can be seen that the bob can vibrate only in a straight horizontal sense, or through an arc of infinite radius. For this reason the device is called the "Infinity Pendulum." Of course when thus adjusted there is no motion and the bob rests at any amplitude as gravity has no chance to produce motion.

By placing the clamp at the very top of the bar the arc of vibration of the bob becomes inverted, that is the center of the arc is below instead of above the bob, and the bob due to its own weight moves out from the point of zero amplitude.

The arcs or curves of the bob (a few are faintly discernible in the picture) are not claimed to be perfectly circular but are practically so when the amplitude is small.

The apparatus can be improvised and improved. Friction should be reduced to the minimum.

As to the possibility of application of the mechanical principles of this device to means of producing curves, or governing speeds, or merely as a demonstration piece, others may judge.

FILTER EQUATIONS

R. R. RAMSEY, Indiana University

The equations for T-type filters are derived in several books. These derivations involve several pages of mathematical discussion. Pierce (Electrical Oscillations and Electric Waves, p. 264-323) devotes a chapter of about forty pages to the subject.

It seems to me that these equations can be derived in a much more simple manner and in a way which gives much more insight to what happens in the circuit.

The method is much the same as the solution of the equations for a transformer as is found in many text books. Starling's Electricity and Magnetism, p. 360, is one place where these equations are derived. The essential points of these transformer results are that the equivalent primary resistance is the actual resistance of the primary plus the resistance of the secondary multiplied by the coupling factor $(M\omega/Z_2)^2$ where M is the mutual inductance and ω is $2\pi n$, n being the frequency.

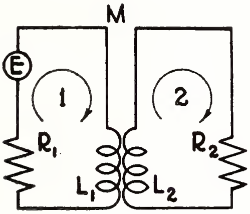


Figure 1.

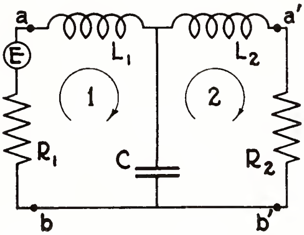


Figure 2.

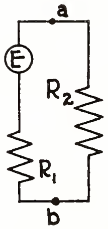


Figure 3.

Figure 1 shows the connections of an ordinary transformer in which the primary resistance is R_1 plus the equivalent resistance of R_2. Figure 3 shows a generator whose resistance R_1, connected to a load of R_2. Figure 2 shows the same generator connected to the load through a "low pass" filter. If the filter is constructed for this circuit R_2 is effectively connected direct to the generator.

The equivalent primary reactance is the primary reactance minus the secondary reactance multiplied by the same coupling factor.

A T-type low pass filter is represented by the diagram, Figure 2. In this curcuit the coupling is capacitance coupling instead of mutual inductance coupling as we have in the transformer.

The differential equations for the primary and secondary are as follows:

$$(1)\quad I_1R_2 + L_1\frac{dI_2}{dt} + \int\frac{I_1dt}{C} = Ee^{i\omega t} + \int\frac{I_2dt}{C}$$

$$(2)\quad I_2R_2 + L_2\frac{dI_2}{dt} + \int\frac{I_2dt}{C} = \int\frac{I_1dt}{C}$$

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In which we have written, for the sake of simplicity, $L_1 = L_2 = L$, L for ½L and have assumed the E.M.F. to be $Ee^{i\omega t}$, where $E(\cos\omega t + i\sin\omega t) = Ee^{i\omega t}$.

If we let $I_1 = Ae^{i\omega t}$ and $I_2 = Be^{i\omega t}$ we get

$$(3)\quad A\left[R_1 + i\left(L\omega - \frac{1}{C\omega}\right)\right]e^{i\omega t} = \left[E - iB\frac{1}{C\omega}\right]e^{i\omega t}$$

$$(4)\quad B\left[R_2 + i\left(L\omega - \frac{1}{C\omega}\right)\right]e^{i\omega t} = -Ai\frac{1}{C\omega}e^{i\omega t}$$

Canceling out $e^{i\omega t}$ we get,

$$(5)\quad A\left[R_1 + i\left(L\omega - \frac{1}{C\omega}\right)\right] = E - iB\frac{1}{C\omega}$$

$$(6)\quad B\left[R_2 + i\left(L\omega - \frac{1}{C\omega}\right)\right] = -iA\frac{1}{C\omega}$$

Solving for the value of B in (6) we have,

$$(7)\quad B = -\frac{iA\dfrac{1}{C\omega}}{R_2 + i\left(L\omega - \dfrac{1}{C\omega}\right)}$$

Substituting this value in (5) we have,

$$(8)\quad A\left[R_1 + i\left(L\omega - \frac{1}{C\omega}\right)\right. = E - \frac{A\left(\dfrac{1}{C\omega}\right)}{R_2 + i\left(L\omega - \dfrac{1}{C\omega}\right)}$$

Rationalizing the denominator of the right hand term of (8) we have

$$(9)\quad A\left[R_1 + i\left(L\omega - \frac{1}{C\omega}\right)\right] = E - A\frac{R_2 - i\left(L\omega - \dfrac{1}{C\omega}\right)\left(\dfrac{1}{C\omega}\right)^2}{R_2^2 + \left(L\omega - \dfrac{1}{C\omega}\right)^2}$$

Collecting the reals and imaginaries we have,

$$(10)\quad A\left[R_1 + \frac{R_2\left(\dfrac{1}{C\omega}\right)^2}{R_2^2 + \left(L\omega - \dfrac{1}{C\omega}\right)^2} + i\left[L\omega - \frac{1}{C\omega}\right] - \frac{\left(\dfrac{1}{C\omega}\right)^2}{R_2^2 + \left(L\omega - \dfrac{1}{C\omega}\right)^2}\left(L\omega - \frac{1}{C\omega}\right)\right] = E$$

In this it will be seen that the equivalent resistance of the primary link of the chain is the real term and the reactance of the primary is the imaginary term.

In a balanced circuit we should have the input and the output impedances equal where the connections are as in Figure 3. Thus before the filter is inserted we have $R_1 = R_2$.

When the filter is inserted as in Figure 2, the load on the generator is R_2 if the coupling coefficient,

$$\left(\frac{1}{C\omega}\right)^2 \Big/ \left[R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2\right]$$

is made equal to unity.

Equating the coefficient to unity we have,

$$R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2 = \left(\frac{1}{C\omega}\right)^2 \tag{11}$$

from which we get

$$R = \sqrt{\frac{2L}{C} - L^2\omega^2} \tag{12}$$

This is approximately equal to $\sqrt{\frac{2L}{C}}$ if the frequency is not near the cut off frequency. When the frequency becomes greater than the cut off frequency the value of R becomes imaginary. To find this critical frequency we equate the value under the radical in (12) to zero and we have,

$$L^2\omega^2 = \frac{2L}{C} \tag{13}$$

Solving for ω or $2\pi n$ we have,

$$\omega = 2\pi n = \sqrt{\frac{2}{LC}}$$

If instead of the quantity L we insert $\frac{1}{2}L$ we have,

$$R = \sqrt{\frac{L}{C}} \quad \text{and} \quad n = \frac{1}{2\pi} \frac{2}{\sqrt{LC}} \tag{14}$$

These are the usual values given for R and n.

In the imaginary term of equation (10) if the coupling coefficient is unity the reactance term becomes zero. Thus if the load in Figure 3 is a pure resistance R, the load of the generator in Figure 2 is a pure resistance, R.

From the value of R and n as given in equations (14) we get

$$L = 2R/\omega = .3183\frac{R}{n} \text{ Henries} \quad \text{and} \quad C = \frac{2}{\omega R} = .3183/nR \text{ Microfarads.}$$

These are the values, L and C used when one is constructing a low pass filter to be used in a circuit whose characteristic impedance is R and a cut off frequency n.

It seems to me that this derivation is much more simple, and at the same time it shows that the reactance terms of the filter cancel each other and that the resistance of the load is transferred bodily, as it were, from the second link to the first link and effectively is connected directly to the generator.

COMPARATIVE ERYTHROCYTE COUNTS OF REPRESENTATIVE VERTEBRATES

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During the course of regular laboratory work in Physiology, a question arose as to the normal erythrocyte count of some of our common vertebrates. A preliminary survey of the literature revealed little or no information on the subject. At the suggestion of Dr. C. P. Hickman, the authors undertook to determine the normal count in such common vertebrates as were easily available. We wish here to acknowledge our sincere appreciation to him for his help and interest in this work.

Attempts were made to secure representative members of all five classes of vertebrates, especially those in common laboratory use. All are inland forms except certain sea fishes that were procured at the Marine Biological Laboratory at Woods Hole. It should be stated that the figure presented for many of the animals is based on one individual only and should be confirmed on several individuals before it is accepted as conclusive. All animals used were apparently in normal healthy condition. In no case were pregnant animals used.

An American Standard haemocytometer with a Levy counting chamber, improved Neubaur double ruling was used. The blood was diluted with Hayem's solution. The blood was withdrawn from the most convenient place in the body. The place of extraction is indicated in the table. Anesthesia was used only on those animals which could *not* be handled otherwise.

Results are collected in the following table:

Animal	No. of animals used	Total No. of counts made	Point of extraction of blood	Anaes-thesia	Average of all counts per cu. mm.
Mammals					
Cavia porcellus					
adult	1	5	tail	no	8,941,000
young	1	3	tail	no	6,013,000
Mus muscalus	2	10	tail	yes	5,442,500
Vespertilio subulatus	2	5	wing	yes	9,502,000
Marmota monax	1	3	heart	no	2,528,000
Felis domestica (6 weeks old)	3	8	ear	no	5,146,250
Mus norvegicus	2	5	heart	no	2,616,250
Albino rat	1	9	tail	no	9,306,000
Birds					
Gallus domesticus	2	10	comb	no	2,267,000
Passer domesticus	1	5	heart	no	3,258,000

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Animal	No. of animals used	Total No. of counts made	Point of extraction of blood	Anaes-thesia	Average of all counts per cu. mm.
Reptiles					
Terrapene carolina	1	14	femoral artery	no	619,200
Coluber constrictor	1	10	post-cava	yes	777,000
Heterodon contortrix	1	16	post-cava	yes	603,100
Amphibians					
Eurycea bislineata	2	10	heart	no	393,300
Plethedon cinereus	2	10	heart	no	252,800
Rana catesbeiana					
tadpole	6	24	tail	no	242,000
adult	3	37	web of foot	no	441,500
Rana pipiens	1	10	web of foot	no	378,000
Rana clamitans	1	4	web of foot	no	817,500
Fishes					
Carassius auratus	2	10	heart	no	508,000
Prionotus strigalus	2	4	heart	no	1,852,500
Tautoga onitis	2	4	heart	no	2,112,500
Fundulus heteroclitus	2	3	heart	no	983,300
Fundulus majalis	2	4	heart	no	1,747,500

While the study is too limited to safely draw conclusions from, one or two general inferences are perhaps hinted at.

1. Much more work needs to be done before the normal erythrocyte count of most vertebrates is established with accuracy.

2. In all cases where comparisons were available, the young animal has a lower count than the adult. This is in accord with such literature as we have been able to find.

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REVISION OF AND ADDITIONS TO THE LIST OF ARANEAE (SPIDERS) OF INDIANA

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Publications of a taxonomic nature dealing with the order Araneae (Spiders) of Indiana are few in number. The principal work of this kind is that of Nathan Banks, former Custodian of the Section of Arachnida of the United States National Museum. The material for Bank's work was largely derived from the collections of W. S. Blatchley, Dr. Mel F. Cook, Professor W. K. Moenkhaus, and A. M. Banta.

Previous to the report of Banks (1906), Emerton (1875), Packard (1888) and Blatchley (1896) had published works dealing with spiders of caves. The work of Blatchley only, had to do especially with the Indiana Cave Spiders. In this work seven species, *Meta menardi*-Latr.; *Dolomedes urinator*-Htz.; *Tmeticus tridentatus*-Em.; *Nesticus carteri*-Em.; *Phanetta subterannea*-Em.; *Tegenaria cavicola*-n-sp.; and *Theridium porteri*-n-sp., were reported, the last two being described as new. All the species described in this and the other papers are included in the "Preliminary List" of Banks.

Subsequent to the work of Banks, papers on cave spiders by Banta (1907) and McIndoo (1910 and 1911) were published. The species described with the exception of *Linyphia weyeri*-Em. are also in the Banks List.

So far as I have been able to determine from the Zoological Record and the Concilium Bibliographicum no other papers listing additional species of spiders have been published.

Since the writer has collected and identified in Indiana a number of spiders not included in the paper of Banks it seemed desirable to add these to the list of known spiders. The original intention was to merely enumerate the different species. It soon bcame evident, however, that this would not suffice. Since the report of Banks, nearly a quarter of a century ago, our knowledge of spiders has increased greatly. Numerous morphological and biological observations which have been made have greatly aided in the understanding of the interrelations of the group. A complete synonomy of all spiders described prior to 1911 has been given us by Petrunkevitch. New genera have been added and many changes made in those already in use, with the result that many species have been changed from the genera to which they were originally assigned. All of the above and many other progressive changes have tended to make the Synoptic Table of families and genera, the arrangement of the genera, and the specific name recorded by Banks, of little value to the student of the group. In order to bring about unification and uniformity of arrangement it was deemed advisable to extend the scope of this work. The purpose of the present paper is therefore not merely to list the additional species but to incorporate

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these with the previously reported ones in a system that most nearly approximates the present knowledge of the group. This has necessarily meant a rather extensive revision of the lists of known spiders.

The order of the families and genera is that given in the Systema Aranearum by Petrunkevitch (1928). The specific name except for those given after 1911, is that given in the Synonymic Index-Catalogue by the same author. In some instances the same species has been described under several names by different arachnologists. No attempt has been made to give a synonomy. The reader is referred to the Index-Catalogue for this. For the most part, the name given is that by which the species is best known. In some instances a spider is best known by one of the synonyms and most frequently described by American students of the group under such. Confusion likely to result from the nomenclature given is, however, compensated by advantages accruing from adherence to the rule of priority.

A total of 148 species is reported by Banks. Of these *Clubiona triloba* and *Singa hentzi* were new and were so described. One form *Tibellus duttoni*—Em., is probably a duplicate of *Tibellus oblongus*—Walck., thus leaving 147 species. Another species, *Linyphia weyeri*—Em., has since been reported from Marengo Cave, Crawford County, by McIndoo (1911). To these 148 spiders the writer adds 70 species, thus making a total of 218 known spiders for the state.

The arrangement of the families and genera as stated is that of the Systema Aranearum. Of the eight families comprising the sub-order Mygalomorphae only one is represented. Of the 46 families comprising the sub-order Arachnomorphae nineteen are represented. These are underscored and the number of species present is indicated. The species have been arranged alphabetically for each genus and are numbered merely for convenience. If the name given by Banks for the species is now known as a synonym it follows immediately after the specific name. The spiders reported by Banks are marked by a B, the additional species now listed by an E. The localities from which these have been reported are indicated. Spiders from Putnam County were collected by Dr. Mel Cook; from Huntingburg by Professor Moenkhaus; from Indiana caves by Banta and Blatchley; from other localities, except Nashville, Crooked Lake, Richmond and Valparaiso, by Blatchley. Spiders from these localities were collected by the writer. No mention is made of the whereabouts of the species described by Banks. These are possibly now a part of the collection of the National Museum. The additional spiders herein reported and specimens of approximately one-half the species reported by Banks are in the collection of the author at Valparaiso University.

CLASSIFICATION OF RECENT SPIDERS
(To Family Only)

Order ARANEAE

I—Sub-Order LIPHISTIOMORPHAE

1. Family *Liphistiidae*

II—Sub-Order MYGALOMORPHAE

First Branch *Nelipoda*

2. Family *Ctenizidae*
3. Family *Atypidae* 1
4. Family *Migidae*
5. Family *Dipluridae*
6. Family *Paratropididae*
7. Family *Pycnothelidae*

Second Branch *Hypodemata*

8. Family *Barychelidae*
9. Family *Theraphosidae*

III—Sub-Order ARACHNOMORPHAE

First Branch *Tetrasticta*

10. Family *Hypochilidae*
11. Family *Filistatidae*
12. Family *Dysderidae* 1
13. Family *Oonopidae*
14. Family *Hadrotarsidae*
15. Family *Telemidae*
16. Family *Caponiidae*

Second Branch *Trionycha*

17. Family *Oecobiidae*
18. Family *Urocteidae*
19. Family *Psechridae*
20. Family *Tengellidae*
21. Family *Amaurobidae* 2
22. Family *Agelenidae* 13
23. Family *Hersiliidae*
24. Family *Zodariidae*
25. Family *Palpimanidae*
26. Family *Eresidae*
27. Family *Pisauridae* 5
28. Family *Lycosidae* 22
29. Family *Oxyopidae* 1
30. Family *Senoculidae*
31. Family *Leptonetidae*
32. Family *Sicariidae* 1
33. Family *Dictynidae* 6
34. Family *Theridiidae* 18

35. Family *Pholcidae* 1
36. Family *Linyphiidae* 31
37. Family *Archaeidae*
38. Family *Uloboridae* 2
39. Family *Dinopidae*
40. Family *Argiopidae* 40
41. Family *Mimetidae* 2

Third Branch *Dionycha*

42. Family *Zoropsidae*
43. Family *Acanthoctenidae*
44. Family *Ctenidae* 1
45. Family *Drassidae* 3
46. Family *Ammoxenidae*
47. Family *Prodidomidae*
48. Family *Homalonychidae*
49. Family *Sparassidae*
50. Family *Selenopidae*
51. Family *Platoridae*
52. Family *Thomisidae* 23
53. Family *Aphantochilidae*
54. Family *Clubionidae* 17
55. Family *Attidae* 28

LIST OF THE SPIDERS OF INDIANA, WITH LOCALITIES

3. *Atypidae*

1. *Atypus milberti*-Walck.-B. Wyandotte Cave; New Harmony (Dransfield).

12. *Dysderidae*

2. *Ariadne bicolor*-Htz.-B. Wyandotte; Mitchell; Mecca; Crooked Lake; Richmond; Valparaiso.

21. *Amaurobidae*

3. *Amaurobius americanus*-Em.-E. Richmond.

4. *Amaurobius bennetti*-Blackwall.-B. Truetts Cave (Banta); Richmond; Crooked Lake.

22. *Agalenidae*

5. *Agalena naevia*-Walck.-B. Tippecanoe Lake; Vincennes; North Vernon; New Albany; Clear Lake; Marion County; Greencastle; Huntingburg; Richmond; Crooked Lake; Nashville; Valparaiso.

6. *Cicurina arcuata*-Keys.-B. Bass Lake; Richmond; Valparaiso.

7. *Cicurina brevis*-Em.-B. Bass Lake; Richmond.

8. *Cicurina pallida*-Keys.-B. Wyandotte; Bass Lake; Putnam County; Richmond.

9. *Coelotes hybridus*-Em.-E. Richmond.

10. *Coelotes longitarsus*.-Em.-B. New Harmony; Richmond.

11. *Coelotes montanus*-Em.-E. Richmond.

12. *Coras medicinalis*-Htz.-B. Putnam County; Richmond.

13. *Tegenaria cavicola*-Banks.-B. Salt Peter Cave, Crawford County.

14. *Tegenaria domestica*-Clerck. (*Tegenaria derhamia*-Scop.)-B. Wyandotte; Greencastle; Twin Cave (Banta); Richmond; Crooked Lake; Valparaiso.

15. *Hahnia agilis*-Keys.-E. Richmond; Crooked Lake.

16. *Hahnia cinera*-Em.-E. Richmond; Crooked Lake.

17. *Hahnia radula*-Em.-E. Richmond.

27. *Pisauridae*

18. *Pisaurina mira*-Walck. (*Pisaurina undata*-Banks)-B. Arlington; Bass Lake; Shoals; Culver; Greencastle; Huntingburg; Richmond; Crooked Lake; Valparaiso; Nashville.

19. *Pisaurina subinflata*-Htz.-B. New Harmony; North Vernon.

20. *Dolomedes tenebrosus*-Htz.-B. Wyandotte; Bass Lake; Mitchell; Medora; Cypres Swamp; Knox County; Lake Maxinkuckee; Gibson; Wilders; Greencastle; Richmond; Crooked Lake; Valparaiso; Nashville.

21. *Dolomedes triton*-Walck. (*Dolomedes sexpunctatus*-Htz.)-B. Tippecanoe Lake; Greencastle.

22. *Dolomedes urinator*-Htz.-B. Mitchell; Donaldson's Cave (Blatchley).

28. *Lycosidae*

23. *Allocosa funerea*-Htz.-B. Knox County; Richmond.

24. *Arctosa cinerea*-Fabricus. (*Trochosa cinera*-Fab.)-B. Hammond; Grand Chain; Pine; Greencastle.

25. *Geolycosa fatifera*-Htz. (*Lycosa fatifera*-Htz.)-B. Wyandotte; Bass Lake; New Harmony; Culver; Marion County.

26. *Lycosa avara*-Keys.-B. North Vernon.

27. *Lycosa avida*-Walck. (*Lycosa erratica*-Htz.)-B. Hammond; Richmond.

28. *Lycosa caroliensis*-Walck.-B. Wyandotte; North Vernon; La-Porte County.

29. *Lycosa frondicola*-Em.-B. Mitchell; North Vernon; New Albany; Huntingburg.

30. *Lycosa gulosa*-Walck. (*Lycosa kochii*-Em.)-B. Tippecanoe Lake; Wyandotte; Bass Lake; Grand Chain; Medora; Richmond.

31. *Lycosa helluo*-Walck.-B. Tippecanoe Lake; Arlington; Bass Lake; Mitchell; Grand Chain; Medora; Mecca; Jeffersonville; Marion County; Huntingburg.

32. *Lycosa pratense*-Em.B. Vincennes; Wyandotte; Bass Lake; Medora; Pine.

33. *Lycosa punctulata*-Htz.-B. North Vernon; Greencastle.

34. *Lycosa rabida*-Walck. (*Lycosa scutulata*-Htz.)-B. Mitchell; Greencastle; Huntingburg; Richmond.

35. *Pirata febriculosus*-Becker.-E. Richmond.

36. *Pirata insularis*-Em.-B. Hammond; Valparaiso.

37. *Pirata minutus*-Em.-E. Richmond.

38. *Pirata marxia*-Stone. (*Pirata piratica*-Clerck)-B. Clear Lake; Knox County; Richmond.

39. *Schizocosa bilineata*-Em.-E. Richmond; Valparaiso.

40. *Schizocosa crassipes*-Walck. (*Lycosa ocreata*-Htz.-B. Tippecanoe Lake; Mitchell; Vawter Park; LaPorte County; Valparaiso.

41. *Schizocosa saltatrix*-Htz. (*Lycosa gracilis*-Banks)-B. Wyandotte.

42. *Pardosa flavipalpis*-F. Cambridge. (*Pardosa flavipes*-Keys)-B. Bass Lake; Jeffersonville; Huntingburg.

43. *Pardosa lepidicina*-Em.-B. Kosciusko County.

44. *Pardosa milvina*-Htz.-E. Richmond.

29. *Oxyopidae*

45. *Oxyopis salticus*-Htz.-E. Richmond.

32. *Sicariidae*

46. *Scytodes thoracica*-Latr.-E. Richmond.

33. *Dictynidae*

47. *Dictyna foliacea*-Htz.-E. Richmond; Crooked Lake; Valparaiso.

48. *Dictyna frondea*-Em.-B. Hammond; Arlington; Marshall County.

49. *Dictyna minuta*-Em.-E. Richmond; Crooked Lake; Valparaiso.

50. *Dictyna sublata*-Htz.-B. Tippecanoe Lake; Grand Chain; Vawter Park; Richmond; Crooked Lake; Valparaiso.

51. *Lathys foxii*-Marx.-E. Richmond.

52. *Lathys pallida*-Em.-E. Richmond.

34. *Theridiidae*

53. *Asagena americana*-Em.-B. Wyandotte; Richmond.

54. *Pedanostethus riparius*-Keys.-B. Knox County; Richmond.

55. *Pedanostethus primulus*-Em.-E. Richmond.

56. *Crustulina guttata*-Wider.-E. Richmond; Crooked Lake; Valparaiso.

57. *Steatoda borealis*-Htz.-B. Greencastle; Richmond; Valparaiso.

58. *Latrodectus mactans*-Fab.-B. Wyandotte; North Vernon; Shoals; New Albany; Greencastle; Huntingburg.

59. *Argyrodes tigronum*-Htz.-B. Twin Cave (Banta).

60. *Euryopis funebris*-Htz.-B. New Harmony; Richmond.

61. *Theridion differens*-Em.-B. Arlington; Bass Lake; Richmond; Crooked Lake; Valparaiso; Nashville.

62. *Theridion frondeum*-Htz.-B. Vincennes; Grand Chain; Richmond; Crooked Lake; Valparaiso.

63. *Theridion kentuckyense*-Keys.-B. Mayfield's Cave; Twin Cave (Banta).

64. *Theridion murarium*-Em.-B. Hammond; Arlington.

65. *Theridion pennsylvanicus*-Em.-E. Richmond; Crooked Lake.

66. *Theridion porteri*-Banks.-B. Porter and Truetts Caves; Mayfield's Cave; Monroe County (McIndoo).

67. *Theridion spirale*-Em.-B. Pine, Lake County.

68. *Theridion tepidariorum*-C. Koch.-B. Kosciusko County; Greencastle; Richmond; Valparaiso.

69. *Theridula opulenta*-Walck.-E. Richmond.

70. *Nesticus carteri*-Em.-B. Bradford Cave (Emerton 1875); Marengo Cave (Banta); Porter, Coon, and Marengo Caves (Blatchley, 1896).

35. *Pholcidae*

71. *Pholcus phalangioides*-Fuesslin.-E. Richmond; Crooked Lake.

36. *Linyphiidae*

72. *Bathyphantes canadensis*-Em.-E. Richmond.

73. *Bathyphantes micaria*-Em.-E. Richmond.

74. *Bathyphantes nigrinus*-Westring.-E. Richmond.

75. *Bathyphantes unimaculatus*-Banks.-E. Valparaiso.

76. *Bathyphantes Zebra*-Em.-E. Richmond.

77. *Linyphia clathrata*-Sundervall.-E. Richmond.

78. *Linyphia conferta*-Htz.-E. Richmond; Crooked Lake; Valparaiso.

79. *Linyphia lineata*-Linnaeus. (*Bolyphantes lineata*-Keys)-B. Greencastle; Richmond.

80. *Linyphia marginata*-C. Koch.-B. Arlington; Wyandotte; Greencastle; Richmond; Crooked Lake; Valparaiso.

81. *Linyphia phrygiana*-C. Koch.-B. Culver; Richmond; Crooked Lake; Nashville.

82. *Linyphia pusilla*-Sundervall.-E. Richmond.

83. *Linyphia weyeri*-Em.-McIndoo (1911). Marengo Cave, Crawford County.

84. *Microneta cornupalpis*-Camb.-E. Richmond.

85. *Troglophantes cavernicolus*-Keys. (*Willibaldi cavernicola*-Keys)-B. Donnelsons Cave (Banta); Mayfield's Cave, Monroe County; Hamer's Cave; Shawnee, Lawrence County (McIndoo).

86. *Ceraticelus emertoni*-Camb.-E. Richmond.

87. *Ceraticelus minuta*-Em.-E. Richmond; Crooked Lake; Valparaiso.

88. *Ceratinella brunnea*-Em.-E. Richmond; Crooked Lake; Valparaiso.

89. *Gongylidiellium pallidum*-Em.-E. Richmond; Crooked Lake.

90. *Oedothorax bidentatus*-Em. (*gonglydium tridentatus*-Em.)-B. Porter Cave, Owen County (Blatchley).

91. *Oedothorax montiferus*-Em.-E. Richmond.

92. *Oedothorax platyrhinus*-Crosby.-E. Richmond.

93. *Oedothorax probatus*-Cambridge.-E. Richmond; Crooked Lake; Valparaiso.

94. *Prosopotheca minuta*-Em.-E. Richmond.

95. *Tmeticus aestivalis*-Em.-E. Richmond; Crooked Lake; Valparaiso.

96. *Ceratinopsis interpres*-Cambridge.-E. Richmond; Crooked Lake; Valparaiso; Nashville.

97. *Diplocephalus exiguus*-Banks-E. Richmond.

98. *Erigone infernalis*-Keys.-B. Twin Cave (Banta); Mayfield's Cave, Monroe County (McIndoo).

99. *Erigone longipalpis*-Sundervall-B. Arlington.

100. *Grammonota inornata*-Em.-E. Richmond.

101. *Phanetta subterranea*-Em.-B. Wyandotte Cave (Blatchley); Truetts Cave (Banta); Marengo Cave and Salt Peter Cave, Crawford County (McIndoo).

102. *Trachelocamptus rostratus*-Em.-E. Richmond; Crooked Lake.

38. *Uloboridae*

103. *Uloborus americana*-Walck.-E. Richmond; Crooked Lake; Valparaiso.

104. *Hyptiotes cavaticus*-Htz.-E. Richmond; Crooked Lake.

40. *Argiopidae*

105. *Arigope aurantia*-Lucas.-B. Maxinkuckee; Greencastle; Richmond; Crooked Lake; Valparaiso; Nashville.

106. *Argiope trifasciata*-Forskal. (*Argiope transversa*-Em.)-B. Richmond; Valparaiso; Nashville.

107. *Acacesia foliata*-Htz.-B. Grand Chain; Greencastle; Richmond.

108. *Araneus angulatus*-Clerck. (*Epeira angulata*-Clerck)-B. Greencastle; Richmond.

109. *Araneus arabesca*-Walck. (*Epeira trivittata*-Keys.)-B. Tippecanoe Lake; Hammond; Vincennes; Arlington; Wyandotte; Bass Lake; Culver; Wilders; Greencastle; Richmond; Crooked Lake; Valparaiso.

110. *Araneus arenatus*-Walck. (*Epeira venusta*-Htz.)-B. Vincennes; Wyandotte; Montezuma; Knox; Greencastle; Richmond; Crooked Lake.

111. *Araneus benjaminus*-Walck. (*Epeira domicilorum*-Htz.)-B. Grand Chain; Greencastle; Huntingburg.

112. *Araneus cavaticus*-Keys.-E. Richmond.

113. *Araneus cornutus*-Clerck. (*Epeira strix*-Htz.-B. Tippecanoe Lake; Vincennes; Arlington; Grand Chain; Vawter Park; Culver, Knox; Jeffersonville; Greencastle; Richmond.

114. *Araneus cucurbitinus*-Clerck. (*Epeira displicata*-Htz.)-B. Tippecanoe Lake; Grand Chain; Attica; Shoals; Vawter Park.

115. *Araneus ectypus*-Walck. (*Epeira infumata*-Htz.)-B. Grand Chain; Richmond.

116. *Araneus hentzi*-Banks. (*Singa hentzi*-Banks)-B. Cannelton.

117. *Araneus labyrintheus*-Htz. (*Epeira labyrinthea*-Htz.)-B. Greencastle.

118. *Araneus marmoreus*-Clerck. (*Epeira insularis*-Htz.)-B. Vincennes; Mitchell; Montezuma; Marion County; Greencastle; Richmond; Crooked Lake; Valparaiso; Nashville.

119. *Araneus nigripes*-Keys. (*Singa nigripes*-Keys)-B. Grand Chain.

120. *Araneus pegnia*-Walck. (*Epeira globosa*-Keys)-B. Greencastle.

121. *Araneus sericatus*-Clerck. (*Epeira sclopetaria*-Htz.)-B. Greencastle.

122. *Araneus stellatus*-Walck. (*Plectana stellata*-Htz.)-B. Vincennes; Bass Lake; Grand Chain; North Vernon; Greencastle.

123. *Araneus thaddeus*-Htz. (*Epeira thaddeus*-Htz.)-B. Greencastle.

124. *Araneus trifolium*-Htz. (*Epeira trifolium*-Htz.)-B. Culver; Greencastle; Crooked Lake; Richmond; Valparaiso.

125. *Araneus varians*-nom. nov. (*Singa variabilis*-Em.)-B. Tippecanoe Lake.

126. *Cyclosa turbinata*-Walck. (*Cyclosa caudata*-Htz.)-B. Greencastle.

127. *Eustala anastera*-Walck. (*Epeira prompta*-Htz.)-B. Richmond; Valparaiso.

128. *Mangora gibberosa*-Htz.-E. Richmond; Valparaiso; Nashville.

129. *Mangora placida*-Htz.-B. Wyandotte; New Harmony.

130. *Glyptocranium bisaccatum*-Em.-E. Richmond.

131. *Glyptocranium cornigerum*-Htz. (*Ordgarius cornigerum*-Htz.)-B. Greencastle.

132. *Meta menardi*-Latr.-B. Mitchell; Greencastle; Strong Cave; Twin Cave (Banta); Mayfields, Strong, Donaldson's, Clifty, Wyandotte, and Salt Peter Caves (Blatchley).

133. *Nephila clavipes*-Linnaeus.-E. Richmond.

134. *Leucauge Venusta*-Walck. (*Leucauge hortorum*-Htz.)-B. Arlington; Grand Chain; New Castle; Richmond; Crooked Lake; Valparaiso.

135. *Pachygnatha tristriata*-C. Koch.-B. New Harmony; Richmond.

136. *Pachygnatha xanthostoma*-C. Koch.-E. Richmond.

137. *Tetragnatha elongator*-Walck. (*Tetragnatha grallator*-Htz.)-B. Tippecanoe Lake; Arlington; Kosciusko County; Huntingburg; Richmond; Crooked Lake; Valparaiso.

138. *Tetragnatha extensa*-Linnaeus.-B. Tippecanoe Lake; Vincennes; Grand Chain; Culver; Knox County.

139. *Tetragnatha laboriosa*-Htz.-B. Tippecanoe Lake; Hammond; Arlington; Wyandotte; Mitchell; Grand Chain; Attica; Vawter; Pine; Wilders; Greencastle; Richmond; Crooked Lake; Nashville.

140. *Eugnatha straminea*-Emerton.-B. Tippecanoe Lake.

141. *Theridiosoma gemmosum*-L. Koch. (Cambr.)-B. Mayfield's Cave (Banta).

142. *Micrathena gracilis*-Walck. (*Arcosoma rugosa*-Htz.)-B. Wyandotte; Greencastle Richmond; Valparaiso.

143. *Micrathena reduviana*-Walck. (*Acrosoma mitrata*-Htz.)-B.

144. *Micrathena sagittata*-Walck. (*Acrosoma spinea*-Htz.)-B. Vincennes; Wyandotte; Mitchell; Greencastle; Richmond; Valparaiso.

41. *Mimetidae*

145. *Ero furcatus*-Villers.-E. Richmond.

146. *Mimetus interfector*-Htz.-B. Shoals.

44. *Ctenidae*

147. *Anihita punctulata*-Htz. (*Ctenus punctulata*-Htz.)-B. Wyandotte.

45. *Drassidae*

148. *Herpyllus vasifer*-Walck. (*Herpyllus ecclesiasticus*-Htz.)-B. Greencastle; Richmond; Valparaiso.

149. *Sergiolos variegatus*-Htz.-B. Tippecanoe Lake; Richmond; Valparaiso.

150. *Zelotes ater*-Htz. (*Zeloter atra*-Htz.)-B. Wyandotte; Richmond; Crooked Lake; Valparaiso.

52. *Thomisidae*

151. *Philodromus aureolus*-Clerck.-B. Hammond; Vincennes; Knox.

152. *Philodromus minutus*-Banks.-E. Richmond.

153. *Philodromus ornatus*-Banks.-B. Arlington; Wilders.

154. *Philodromus pernix*-Blackwall. (*Philodromus vulgarus*-Htz.)-B. Tippecanoe Lake; Bass Lake; Grand Chain; Pine; Knox County; Greencastle; Richmond.

155. *Philodromus placidus*-Banks.-B. Vincennes; Arlington; Grand Chain; Pine; Culver.

156. *Philodromus rufus*-Walck.-B. Tippecanoe Lake; Arlington.

157. *Tibellus oblongus*-Walck.-B. Pine; Kosciusko County; Wilders; Greencastle; Richmond; Valparaiso; Nashville.

158. *Misumenoides aleatorius*-Htz. (*Runcinia aleatorius*-Htz.)-B. Lake James; Hammond; Grand Chain; Greencastle.

159. *Misumenops americana*-Keys. (*Misumena americana*-Keys)-B. Bass Lake; Grand Chain; Attica; Culver; Knox County; Greencastle; Valparaiso.

160. *Misumenops asperatus*-Htz. (*Misumessus asperatus*-Htz.)-B. Wyandotte; New Harmony; Pine; Huntingburg; Richmond; Valparaiso.

161. *Misumenops oblongus*-Keys. (*Misumessus oblongus*-Keys)-B. Veedersburg; Vawter Park; Greencastle; Richmond; Crooked Lake; Valparaiso.

162. *Oxyptila conspurcata*-Thorell.-B. Cypress Swamp; Pine; Knox County.

163. *Oxyptila monroensis*-Keys.-E. Richmond.

164. *Synaema parvulum*-Keys. (Hentz)-B. Arlington; Grand Chain; Veedersburg; Culver.

165. *Tmarus angulatus*-Walck.-E. Richmond; Crooked Lake.

166. *Xysticus ferox*-Htz. (*Xysticus stomachosus*-Keys.)-B. Vincennes; Arlington; Wyandotte; Bass Lake; Culver; Greencastle; Richmond; Valparaiso.

167. *Xysticus fraternis*-Banks.-E. Richmond; Crooked Lake; Valparaiso.

168. *Xysticus gulosa*-Keys.-B. Wilders.

169. *Xysticus luctans*-C. Koch. (*Xysticus quadrilineatus*-C. Koch)-B. Kosciusko County.

170. *Xysticus nervosus*-Banks.-B. Tippecanoe Lake; Greencastle; Richmond; Valparaiso.

171. *Xysticus transversus*-Banks.-B. New Harmony.

172. *Xysticus triguttatus*-Keys.-B. Hammond; Richmond; Valparaiso.

173. *Xysticus versicolor*-Keys. (*Coriariachne versicolor*-Keys.)-B. Wyandotte; Grand Chain; Mecca; New Albany; Greencastle.

54. *Clubionidae*

174. *Chiracanthium inclusium*-Htz.-B. Vincennes.

175. *Clubioba abbotii*-L. Koch.-B. Arlington.

176. *Clubiona obesa*-Htz.-E. Richmond; Valparaiso.

177. *Clubiona pallens*-Htz.-E. Richmond; Valparaiso.

178. *Clubiona triloba*-Banks.-B. Wyandotte.

179. *Anyphaena gracilis*-Htz.-B. Hammond; Veedersburg.

180. *Anyphaena pectorosa*-L. Koch.-E. Richmond.

181. *Anyphaena saltabunda*-Htz.-E. Richmond; Valparaiso; Nashville.

182. *Agroeca minuta*-Banks.-E. Richmond; Crooked Lake.

183. *Agroeca pratensis*-Em.-B. Arlington.

184. *Phrurolithus alarius*-Htz.-B. Grand Chain; Crooked Lake; Richmond.

185. *Phrurolithus palustris*-Banks.-E. Richmond; Crooked Lake.

186. *Phrurolithus similis*-Banks.-E. Richmond.

187. *Trachelas tranquillus*-Htz.-B. Tippecanoe Lake; Greencastle; Huntingburg; Richmond; Valparaiso.

188. *Castaneira cingulata*-C. Koch.-E. Richmond; Crooked Lake; Valparaiso.

189. *Castaneira descripta*-Htz.-B. Greencastle.

190. *Castaneira longipalpis*-Htz.-B. Tippecanoe Lake; Knox County; Richmond.

55. *Attidae*

191. *Synemosyna formica*-Htz.-B. Arlington; Culver; Richmond.

192. *Thiodina sylvana*-Htz. (*Thiodina retarius*-Htz.)-B. Wyandotte; Grand Chain; Huntingburg.

193. *Maevia vittata*-Htz.-B. Arlington; New Albany; Richmond; Crooked Lake; Valparaiso; Nashville.

194. *Zygoballus bettini*-Peckham.-B. Knox County.

195. *Habrocestum pulex*-Htz.-B. Wyandotte; Richmond; Valparaiso.

196. *Pellenes roseus*-Htz.-E. Crooked Lake; Valparaiso.

197. *Pellenes borealis*-Banks.-E. Crooked Lake.

198. *Phlegra fasciata*-Hahn. (*Phlegra leopardus*-Htz.-B. New Harmony.

199. *Tutelina elegans*-Htz.-B. Hammond; Arlington; Bass Lake; Shoals; Culver; Knox County.

200. *Agassa cyanea*-Htz. (*Homolattus cyanea*-Htz.)-B. Hammond.

201. *Dendryphantes* (*Phidippus*) *audax*-Htz. (*Phidippus audax*-Htz.)-B. Arlington; Bass Lake; New Harmony; Grand Chain; Attica; North Vernon; Culver; Greencastle; Huntingburg; Richmond; Crooked Lake; Valparaiso.

202. *Dendryhpantes* (*Paraphidippus*) *aurantius*-Lucas. (*Phidippus multicolor*-Htz.)-B. Vincennes; Wyandotte; Grand Chain; Shoals; Greencastle.

203. *Dendryphantes* (*Metaphidippus*) *capitatus*-Htz. (*Dendryphantes octavius*-Htz.)-B. Hamomnd; Arlington; Wyandotte; Bass Lake; Grand Chain; Attica; Shoals; Veedersburg; Vawter Park; Pine; New Albany; Culver; Crooked Lake; Valparaiso; Richmond; Nashville.

204. *Dendryphantes* (*Phidippus*) *clarus*-Keys.-E. Richmond; Nashville.

205. *Dendryphantes* (*Phidippus*) *cardinalis*-Htz. (*Phidippus cardinalis*-Htz.)-B. North Vernon.

206. *Dendryphantes* (*Phidippus*) *formosus*-Peckham. (*Philaeus rimator*-Peckham)-B. Greencastle.

207. *Dendryphantes* (*Phidippus*) *insignarius*-C. Koch.-B. Hammond; Arlington.

208. *Dendryphantes* (*Paraphidippus*) *marginatus*-Walck. (*Dendryphantes militaris*-Htz.)-B. Wyandotte; Mitchell.

209. *Dendryphantes* (*Phidippus*) *putnami*-Peckham. (*Phidippus putnami*-Peckham)-B. Knox County; Grand Chain.

210. *Dendryphantes rarus*-Htz.-B. Greencastle.

211. *Dendryphantes* (*Phidippus*) *whitmanni*-Peckham. (*Dendryphantes rufus*-Htz.-B. Vincennes; Wyandotte; Bass Lake; Grand Chain; Wilders; Huntingburg.

212. *Icius hartii*-Em.-E. Richmond; Nashville.

213. *Neon nelli*-Peckham.-E. Richmond; Crooked Lake; Valparaiso; Nashville.

214. *Hyctia pikei*-Peckham.-E. Richmond.

215. *Marpissa undata*-DeGeer.-B. Greencastle; Huntingburg.

216. *Wala mitrata*-Htz.-B. Arlington; Grand Chain; Shoals; Veedersburg; Vawter Park.

217. *Wala palmarum*-Htz.-B. Hammond; Arlington; Pine.

218. *Salticus scenicus*-Clerck.-E. Richmond.

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THE OCCURRENCE OF THE FRESH-WATER MEDUSA NEAR RICHMOND, INDIANA

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The occurrence of the fresh-water medusa has been recorded in this country at rather infrequent intervals since 1908. Payne[1] recorded the presence of the form near Elkhart, Indiana, in 1918. In a personal communication he states that a few occurrences have been reported since that time. Payne established the species as *Craspedacusta ryderi.* He worked out the life history and identified it as the sexual generation of *Microhydra ryderi.* For details of life history, morphology and bibliography the reader is referred to his two papers.[2]

The purpose of this paper is to record the occurrence of the species in a small artificial body of water near Richmond, Indiana, during August and September, 1931. This pond is known as Crescent Lake. It was formed about seventy-five years ago by damming a curve in the Whitewater River to make an ice pond. It is shaped like a horseshoe, with a length of about three hundred yards and a width of about fifty yards. The banks slope sharply to a depth of fifteen to twenty-five feet. The pond is fed by two large springs, so that the water is insured against stagnation. The water is strongly alkaline (averaging pH 8.6) due to the limestone outcroppings along the banks. The pond is leased by a local fishing club and is stocked from time to time with such fish as bass and bluegills. Water fowl make considerable use of the pond during the migration season. In addition to the fish and water birds the most apparent members of the fauna include *Goniobasis livescens, Planaria dorotocephala,* several species of Entomostracha *Hydra viridis* and an apparently undescribed species of *Pelmatohydra.* It is of interest to note that the lake near Elkhart as described by Payne seems to have a close physical correspondence to this pond.

The first specimens of *Craspedacusta* were discovered late in August by Mr. Malcom Stover, a Richmond High School student, whose father owns the land on which the pond lies. The writers first saw them on September thirteenth and kept them under rather constant observation until they finally disappeared September twenty-fourth. The weather during much of this time was unseasonably warm, a temperature of 30 C. not being uncommon. The water, on two occasions when the animals were most numerous, registered 26°C. Also, on two occasions, rains, lowering the temperature to 24° and 23° respectively, were followed by the disappearance of the animals until the temperature rose. This would seem to indicate that a lowering of the temperature interferes with their activity. Payne observed that the animals were most active in bright sunlight. The specimens observed by the writer, however,

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[1] Payne, F. A study of the fresh-water medusa, *Craspedacusta ryderi.* Jour. Morph. 38(3):387-430. 1924.

[2] Further studies on the life history of *Craspedacusta ryderi,* a fresh-water Hydromedusan. Biol. Bull 50(6):433-443. 1926.

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seemed to be most active in the late afternoon and evening. On a number of occasions their activity was noted to increase markedly soon after the sun sank below a high bluff lying just west of the pond. Observations made by flashlight showed the surface of the pond teeming with very active medusae as late as ten o'clock.

While the animals were seen in a number of places in the pond, they were most numerous around an old pier which had been made for landing ice cakes. This seemed to form a shelter from wave action and may have served as a substratum for the hydroid generation. None of these were seen.

The scarcity of these forms, their seemingly erratic behavior and the divergence between my observations of their behavior and those of Payne make them especially challenging for further study.

PROGRESSIVE PARALYSIS OF THE NERVOUS SYSTEM OF HOUSE FLIES BY FORMALDEHYDE AND ANESTHETICS

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Casual observations on house flies which had been poisoned with formaldehyde led to a closer investigation of the paralytic effects of this substance and certain anesthetics. Formaldehyde has been widely used as a poison for house flies because of its simple application. Flies apparently do not object to formaldehyde in fairly weak concentrations (1-5 per cent) and can easily be induced to ingest solutions of 5 per cent or more by the addition of sweet substances. Stronger solutions produce "unpleasant" reactions on the part of the flies, but nevertheless the insects often return for more.

Material and Methods. The following experiments and observations were conducted on more than 100 house flies. Formaldehyde was fed mixed with honey and water. No difficulty was experienced in inducing the flies to imbibe. Anesthetics used were ether, chloroform, and "chlorotone" (chlorobutanol). For ether and chloroform effects the flies were placed in small test tubes (12 mm. diameter) plugged with cotton. Cotton plugs were placed in such a way that a space of approximately 20 mm. was allowed to permit movement. Observations were then made by means of a binocular microscope. Anesthetics were applied by placing a drop of the substance on the cotton, which allowed the vapor to enter the chamber. A very small quantity of the anesthetic was found necessary to produce complete anesthesia. When completely quiet the flies were removed to fresh tubes and allowed to recover. Chloretone was used in two ways. It was fed in a 5 per cent solution made with honey and water as previously explained for formaldehyde. It was also administered through the tracheae by allowing the flies to come in contact with the vapor of the substance in a test tube. Crystals of chloretone were placed in the tubes with the flies. Being a volatile substance its effects were noticed immediately.

Effects of Formaldehyde Ingestion by Flies. The effects of formaldehyde solutions of various strength are identical except for the rate of occurrence of events. Strong solutions produce effects more rapidly than weak ones. Likewise the succession of events occurs more rapidly with strong solutions. However, if two separate feedings of a weak solution are given the effect of the second is that of strongly augmenting the effects of the first. It was noticed also that large flies reacted more quickly than small ones when allowed the same time for feeding. This is apparently not correlated with sex since large and small individuals of both sexes were used and apparently neither sex was

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affected more than the other. The events following feeding always occur in the same order as follows:

1. The proboscis reflex occurs first. After ingestion of some of the mixture the proboscis is projected and withdrawn repeatedly during the activity of the fly. The movement consists of a ventro-cephalad projection and a withdrawal. This same reflex has been noted when flies were fed other harmful substances and is probably due to the presence of an abnormal sensation. The movements of the proboscis occur regularly at intervals of about two seconds. It has often been noticed that an exudate was present at the tip of the oral lobes which often was deposited on the side of the confining tube.

2. Following the proboscis reflex occurs a repeated "cleaning" of the first pair of legs. An absence of "head cleaning" was observed. The first pair of legs were rubbed over the proboscis and then rubbed together against their inner surfaces. Since this does not always occur, little significance is attributed to it.

The above reactions (1 and 2) are preliminary stages, not representing any paralytic effects. Following these the effects are stages of successive paralysis.

3. The apex of the abdomen is next to be affected. Inability to support it free from the surface of the glass is apparent. The flies walk about dragging the posterior portion of the abdomen.

4. The third pair of legs shortly become paralyzed. These are also dragged as the fly pulls itself by means of the first and second pair. Often while at rest the fly assumes an attitude not unlike the *Anopheles* mosquito with the hind legs elevated. That the legs were actually paralyzed was demonstrated by pinching them with tweezers. This produces no reaction on the part of the fly, indicating an insensibility in these appendages. If any of the other legs are so treated the fly immediately reacts by trying to free itself.

5. Following the paralysis of the third pair of legs a period of apparently no additional effects results, the length of which depends upon the strength of the formaldehyde solution and the amount ingested. This period may vary from a few seconds to over an hour.

6. At the end of the above period the second pair of legs become affected and shortly are paralyzed also. The fiy then drags itself by its prothoracic legs.

7. Very soon following the paralysis of the mesothoracic legs the wings and first pair of legs are affected. The interval occurring between the effect on the second and first pair of legs is very brief. In fact, unless the formaldehyde has been given in quite a dilute solution the interval will not be apparent. At this stage the fly can no longer right itself if placed on its back.

8. The final effect is the loss of the proboscis and antennal movements which continue as long as the fly is alive.

Thus we may assume that formaldehyde paralyzes the nervous system of the house fly in a posterio-anterior direction which as will be mentioned later is antagonistic to the physiological gradient theory.

In reference to the definite interval occurring between the paralysis of the third and second pair of legs one might expect to find some anatomical reason such as a gap between the ganglia supplying their respective legs. However, upon dissecting out the thoracic ganglia of the house fly the writer was unable to note any possible explanation in the arrangement of the ganglia since it was observed that the three pairs of ganglia supplying the legs are coalesced into a single large central unit. Therefore, the explanation for the pause must be physiological rather than anatomical.

I have given some evidence to show that the loss of ability to move the appendages is a paralysis, probably nervous since sensation as well as motion disappears. There has been observed also another source of evidence. When formaldehyde is fed to flies in considerable numbers, and they are allowed to fly about at will many can be seen copulating and remaining attached, a condition which does not normally occur. These same flies show a beginning or later stage of paralysis. It is assumed by the writer that paralysis has occurred in the posterior region of the body involving the last abdominal ganglia at least, thereby resulting in an inability to control the muscles of copulation whereby to release themselves.

Effects of Anesthetics, Chloroform. The sequence of events during chloroform anesthesia was observed to be as follows:

1. The proboscis reflex starts as soon as the fly becomes aware of the vapor.

2. At a later period the legs become affected and are paralyzed almost simultaneously. It would be impossible to say definitely in what order the legs are affected, since any pair may be observed to make the last movement.

3. The wings become affected shortly after the legs.

4. The proboscis reflex and antennal twitching are the last actions to be noticed. These may persist for some time after the legs and wings have become immobile.

Recovery from Chloroform Anesthesia. When the insects are removed from the tubes and allowed to recover the actions are manifested in the following order:

1. The proboscis and antennal movements appear first.

2. After some interval of time the legs begin to twitch and definite movements occur. Apparently no definite order exists in recovery of the legs, or possibly the recovery is so rapid that it becomes impossible to detect any definite order.

3. Wing movements follow leg movements until the fly is able to walk or fly. However, the insects are unsteady on their feet for quite a period of time. The legs appear to have lost tonus since instead of being angular and rigid as they are when normal, they are apparently limp with the extremities often appearing curved. This period of unstability ordinarily lasts 30 minutes or longer.

Ether. Very little difference exists between the reactions to chloroform or ether. Recovery is more rapid from ether and the period of instability shorter. It might be mentioned at this point that in spite of the fact that all the legs recover almost simultaneously it appears that the first and second pair are more active than the third pair.

Anesthesia by Chloretone Vapor. Flies were placed in tubes to which were added crystals of chloretone. As soon as anesthesia was complete the flies were removed and recovery observed. The stages of anesthesia are as follows:

1. The proboscis reflex starts immediately after the chloretone vapor is detected.
2. The flies exhibit erratic movements showing lack of co-ordination. Many spasmodic movements occur.
3. The loss of ability to move the legs and wings occurs practically simultaneously as in the cases of ether and chloroform. The final stage in this phase is represented by a twittering of the tarsi of all the legs.
4. The proboscis reflex continues throughout all of the above stages and is the final movement to disappear.

In recovery from chloretone anesthesia the proboscis reflex again appears first followed by leg movements in a disorganized fashion. The legs show loss of muscle tone for long periods following recovery. In very many cases the flies were found dead the following day, indicating incomplete recovery from chloretone.

Effects of Ingestion of Chloretone. Flies which had been fed chloretone (5 per cent solution with honey and water) showed reactions similar to those obtained with formaldehyde. In most cases feeding was difficult due to the odor of the substance. However, the flies returned to imbibe repeatedly although for short intervals only. The sequence of events is as follows:

1. Erratic movements are apparent indicating an abnormal condition.
2. The proboscis reflex starts and continues throughout the successive stages.
3. The third pair of legs become somewhat sluggish.
4. All of the legs become paralyzed almost simultaneously although loss of movement apparently occurs first in the third pair. This stage occurs only when considerable quantities of chloretone have been ingested. Recovery is complete with chloretone feeding, the flies showing no ill effects after complete recovery.

DISCUSSION

Thus we see that the events do not occur in exactly the same order when formaldehyde is ingested by flies as when anesthetics are administered. In the case of formaldehyde, paralysis occurs definitely in an anterior direction. A pause exists between the effects on the last pair of legs and the second pair. This can not be explained by the morphological arrangement of the thoracic ganglia. It is therefore due to some physiological reaction. The proboscis reflex which occurs first is evidently caused by some sensory disturbance and may not be due to the direct action of formaldehyde on the head ganglia.

Since the proboscis movement, together with the antennal twitchings, is last to disappear we can assume that the region of highest metabolic activity, namely the head, is the last to be affected. This result is in direct opposition to the accepted theory of axial, or better, physiological gradients. Since the antennal and proboscis movements are not the first to disappear we must assume either that the head does not represent the region of highest activity or else that the fly is an exception to the accepted theory of susceptibility of physiological gradients.

With anesthetics somewhat similar results have been noted. Here we do not find the clearly marked progression of paralysis of the legs as is the case with formaldehyde poisoning. Nevertheless, here again the movements of those appendages controlled by the cephalic ganglia are the last to disappear.

In the great majority of cases toxic substances, such as HCN, acids, alkalies, etc., affect first the regions of highest metabolic activity. This has been repeatedly demonstrated with simpler animals. Child[1] states that "susceptibility varies directly with, though not necessarily proportionately to, the general protoplasmic activity or rate of metabolism." Evidently the house fly demonstrates regional differences in susceptibility to various toxic agents. The beautiful example of posterio-anterior paralysis by formaldehyde must evidently be accounted for by other means than simply physiological gradients. Could assimilation of the poisonous substance after ingestion be regional and thus affect certain ganglia before others? It scarcely seems probable when we consider that small amounts of the toxin may produce these effects after periods of an hour or more. Certainly in this length of time the formaldehyde would have quite generally penetrated the body substance as a whole.

In return from anesthesia the flies follow the accepted theory of axial gradients, that is to say, the anterior organs revive first and the progression is caudad. This agrees with Child's statement that "the rate and degree of recovery after temporary exposure to a certain range of concentration or intensity varies in the same way," that is, the order and rate of recovery is proportional to the metabolic rate.

CONCLUSIONS

It has been demonstrated that formaldehyde causes a progressive paralysis of the nervous system of the house fly in an anterior direction starting with the posterior end of the abdomen and ending with the mouth parts and antennae.

Anesthetics produce results comparable to formaldehyde although the phases of paralysis are not as distinct as in the case of formaldehyde poisoning.

In recovery from anesthesia the phases occur in the opposite direction, that is to say, the anterior end recovers first and the progression is in a posterior direction.

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[1] Child, C. M. Physiological foundations of behavior. 1924. Holt and Co.

VISIBLE VASO-MOTOR EFFECTS IN THE PULMONARY CIRCULATION OF THE FROG

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Vaso-motor nerves to the lung vessels of the frog have been demonstrated by Luckhardt and Carlson[1]. By means of the perfusion and drop method these authors have carefully proven the existence of vaso-motor effects in the pulmonary circulation of the frog both as a result of sympathetic stimulation and by the introduction of adrenalin and of histamine solutions. They also mention observing the effects directly. The writer also has had the opportunity of visually noting changes in the blood flow in the frog lung, particularly in respect to the capillaries.

The common grass frog, *Rana pipiens*, was used. Individuals were narcotized by placing them in a 10 per cent solution of urethane until they were motionless. This ordinarily required from 30 to 40 minutes for frogs of about 30 grams weight. Apparently the drug did not alter the circulatory movements. Both left and right lungs were observed in the following manner. The frogs were opened by a mid-ventral incision through the sternum and the lung to be examined was lifted carefully when inflated by the frog. The frog was placed on its dorsum with its appendages stretched out slightly, in order to pull the cut sternum aside. The lung, while filled with air, was placed between two microscope slides carefully to avoid injury. The slides were held together by gummed paper labels. This preparation was then laid across the stage of a microscope and the flow of blood observed. Adrenalin solutions of 1:1000 and 1:10,000 in frog saline were added to the far edge of the slide in such a way that the mixture was prevented from reaching any other organs than the lungs to which it flowed by capillarity. A strong binocular dissecting microscope was used in two cases and found satisfactory for observing the flow.

Results. Almost immediately upon contact with the adrenalin solution the lung vessels underwent constriction. A visible decrease in the rate of flow was apparent, in fact a stasis occurred in many regions. In some cases where the corpuscles were not entirely blocked they could be seen bending in a C-shape as they were forced through the narrowed vessels. A short time after the introduction of the adrenalin the lung tissues became edematous, a condition also reported by Luckhardt and Carlson. However, the constriction occurred before this abnormal condition set in so that there is no question in the writer's mind but that the vaso-motor effects were due to the adrenalin. This paper is given as a corroboration of the results of the above authors and to indicate that the constriction is so complete as to change the shape of the corpuscles or to cause stasis.

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[1] Luckhardt, A. B. and Carlson, A. J. 1921. Studies on the visceral sensory nervous system. VIII. On the presence of vaso-motor fibers in the vagus nerve to the pulmonary vessels of the amphibian and reptilian lung. Amer. Jour. Physiol. 56:72-112.

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A COMPARISON OF THE METABOLIC RATES OF VARIOUS INSECTS AS DETERMINED BY CARBON DIOXIDE OUTPUT

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Since insects represent such varied types of activity it is interesting to determine and compare the metabolic rates of different forms. The activity of the insect itself gives us a general idea of the animal's metabolism but measurements of its metabolic rate are far more impressive. It would appear logical to assume that such insects as the Hymenoptera and Diptera should have higher rates of metabolism than the Coleoptera since in general the former are more active forms. The following investigation was carried on with 14 different insects with which 23 determinations were made under similar conditions. The purpose of the work was: (1) to determine how great differences exist in the metabolism of insects of different groups; (2) to ascertain if there exists a standard rate of metabolism for each insect or each species; and (3) to note if a correlation exists between the "activity" of the insect and its metabolic rate.

Historical. A number of metabolic determinations have been made upon insects by various workers. In his important contribution to our knowledge of respiration, Krogh (1916) so admirably summed up the data of previous workers that the writer feels it unnecessary to include these references in this paper. Krogh lists the metabolism of some 12 insects as determined by measurements of oxygen consumption or carbon dioxide output.

Davis and Slater (1926) have demonstrated a higher metabolic rate in small cockroaches than in large ones. Sayle (1928) has likewise shown an inverse relationship between metabolism and body weight with dragon-fly nymphs. Many other investigators have recorded the metabolism of insects during different stages of metamorphosis. This paper is concerned, however, with insects in the imago state only.

Material and Methods. The insects studied are listed in the accompanying table. They represent four orders. In a few cases several determinations were carried out with the same individual and are so noted. In all determinations identical conditions were maintained as far as possible. The insects were placed in a wire screen cage and left in the constant temperature box for several hours (12 or more) to allow their metabolism to become normal. Handling of the insects was avoided as much as possible since it is generally known that this influences the metabolic rate of experimental animals. The effect of handling is perhaps more pronounced with vertebrates than with insects. The writer (1931) in a previous investigation with aquatic in-

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sects could not notice any marked effect on metabolism of carefully handling the insects in wire cages previous to an experiment.

Determinations of carbon dioxide were made by Lund's (1919) method. The only modification was the substitution of the wire screen cage to house the insect. $Ba(OH)_2$ of N/30 and N/100 strength was used, 10 cc. being placed in the insect jar and a like amount in the control jar. Titrations were carried out with N/100 HCl, with two drops of phenolphthalein as an indicator. In most instances the insect was confined in the jar for periods of one hour duration. With extremely small forms (e. g. *Chironomus*) the period was lengthened to two or four hours with the assumption that a better average could be obtained. The insect jars were of 100 cc. capacity which was believed to be sufficient to prevent any effects of diminished oxygen pressures. All determinations were made in a light-proof constant temperature box at 22°±1° C. The insects were weighed and the carbon dioxide output per hour recorded. From these data the metabolic rate was determined. It is given in terms of mgr. of carbon dioxide per hour per gram body weight which is identical with gr. carbon dioxide per kilogram hour, the latter designation being commonly applied to larger animals.

Insect	Wt. in grams.	CO_2 per hour. mgr.	Metabolic rate. CO/$_2$gr. body wt./hr. mgr.
Coleoptera:			
1. Tetraopes	.155	.034	.220
2. Coccinella	.115	.036	.313
3. Coccinella	.115	.051	.443
Diptera:			
4. Musca	.028	.110	3.928
5. Musca	.028	.088	3.142
6. Chironomus	.0067	.013	1.940
Orthoptera:			
7. Microcentrum	.583	.294	.505
8. Microcentrum	.583	.435	.746
9. Melanoplus	.282	.242	.858
10. Melanoplus	.282	.349	1.240
11. Blatta	.088	.151	1.710
12. Blatta	.068	.134	1.970
13. Periplaneta	.502	.396	.788
14. Periplaneta	.502	.376	.749
15. Periplaneta	.475	.327	.689
16. Periplaneta	.475	.382	.804
17. Periplaneta	.475	.407	.855
Hymenoptera:			
18. Vespa	.035	.552	15.770
19. Polistes	.180	.455	2.518
20. Polistes	.179	.625	3.490
21. Polistes	.146	.466	3.190
22. Polistes	.146	.561	3.842
23. Polistes	.146	.514	3.520

Results and Discussion. The results of the determinations are given in the table. There is apparent a very great range of rates for different species, the two extremes being those of *Tetraopes* and *Vespa.* The metabolic rate of the hornet is therefore over 75 times as great as that of the milkweed beetle. Similar extremes in rate are listed in Krogh's summary table of "metabolism of cold-blooded animals at temperatures about 20°." The metabolic rates of the insects listed in the above mentioned table correspond in general to those of the insects used in this investigation.

Not only is there a very great difference in the rates of different types of insects but also a variation in the more closely allied groups. For example, the average metabolic rate of the common *Blatta* is about twice as great as that of its larger relative, *Periplaneta.* The latter insect would average about six times as heavy as the former so the difference can not be accounted for by size alone.

A variation in rate is also apparent with different individuals of the same species and also with different determinations of the same individual. The question arises at this point as to whether or not the carbon dioxide output is an accurate index of metabolism. Assuming that the respiratory quotient is constant for a given individual we can possibly account for the variations in carbon dioxide output as due to slight variations from time to time in the ability of the insect to dispose of its carbon dioxide. This might easily be explained by the air sacs in connection with the tracheae. Lee (1929) has suggested that the air sacs allow a considerable volume of air to be inhaled and exhaled, thus causing a ventilation of the tracheal trunks. Herber and Slifer (1928) have shown that the respiratory movements of the Locustidae are variable. Thus we can easily see a reason for variations in the carbon dioxide output of insects from time to time under similar conditions.

CONCLUSIONS

It has been shown that a considerable difference in metabolic activity exists among the various groups of insects. The highest rate among the groups investigated existed with the Hymenoptera and Diptera. The lowest rates occurred with the Coleoptera; the Orthoptera lying somewhere between.

There is evidence to indicate that a correlation exists between the activity of the insect and its metabolic rate.

By means of carbon dioxide determination a standard metabolic rate can not be shown to exist in a given species or individual. Slight variations in rate occur with each determination under practically identical conditions.

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PHYSIOLOGICAL ASSAY OF GLUCOSIDES, TOXINS AND POISONS ON GOLD FISH, *CARASSIUS AURATUS*

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The object of standardization of the potency of many complex glucosides for which no satisfactory quantitative chemical tests are possible, and the physiological standardization of organic compounds of known constitution, the employment of which depends upon definite potency, the physiological assay of poisons and other related compounds, are among the principal aims of pharmacology. One of the most engaging subjects for the physiologist is the pharmacological study of these agents on the various organs of the body, and the physiological standardization is in many instances a prerequisite to the pharmacological study, to insure working with a compound of definite potency.

It is obvious, therefore, that any method which can insure a greater uniformity and a simplicity of application would be most welcome.

Let us briefly consider for a moment the methods proposed and in vogue for the standardization of digitalis preparations. The U. S. Pharmacopeia recognizes a short method, making use of the frog, *Rana Pipiens*, weighing between 20 and 30 grams and kept at 20 deg., fixing a standard for tincture of digitalis at 6½ milligrams per gram of animal weight as the lethal dose which must cause systolic arrest of the heart. This action must take place by the end of one hour.

Numerous modifications exist of this frog-heart method—the well known Houghton 12-hour method which is of still greater accuracy than the pharmacopeia test. The Focke method is hardly recommendable since it depends upon variable doses to be given throughout the course of the test and, therefore, opens the method to grave chances of inaccuracy. Reed and Vanderlick's Guinea Pig method as modified by Githens and Pittinger, is undoubtedly the finest method of physiological assay for digitalis and digitalis bodies, but it is expensive and time-consuming.

The action of Brody-Hatcher's method is open to the same objection as the method of Focke, in addition to being variable and inaccurate. Pittinger conducted some tests of digitalis on gold fish. The test is made by keeping a gold fish, weighing a gram or over, in 500 c.c. of water at 22 deg. Cent. The minimum lethal dose is that amount of the drug which will cause death by the end of three hours.

This method furnishes the incentive to study the assay on gold fish, and the study has given some very interesting results. By comparison with the guinea pig method we have found that a gold fish

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weighing a gram to a gram and a half in 500 c.c. of water, shows functions exactly the same as an animal of 500 gram weight.

This is the fundamental discovery of our studies. We have found that the 500 c.c. of water in which is placed a gold fish of a gram to a gram and a half functions as an animal weighing 500 grams and with fewer factors of error.

The uniformity of reaction has always been very impressive. Digitalis glucosides or a dose of strychnine, digitalin or any other poison which would cause death within a certain time, would take exactly one-half the time if the amount of water would be decreased to 250 c.c. and if the amount of water were decreased to 400 c.c. the death took place in one-fifth less time, etc.

On increasing the amount of water the lethal qualities were still present but the length of time increased accordingly until the dose was no longer lethal for the larger animal represented by the larger body of water. The test is, therefore, an extremely reliable one for testing the lethal dose per gram of weight of many of the complex glucosides, alkaloids, toxins, poisons, organic compounds, than other methods in vogue. With this method it is easy to maintain the proper temperature, it is easy to observe the effect on the fish at all stages of the drug or poison action, and with carefully developed observation, one can note many interesting actions, some of which will be hereafter related.

Action of Digitalis Glucosides on Gold Fish. The U. S. P. sets a standard of 6½ milligrams on the tincture per gram of frog weight as a standard which should cause arrest of the heart in one hour. When a corresponding amount, 6½ milligrams multiplied by 500 c.c. of water with a gold fish weighing a gram, 3½ grams U. S. P. standardized tincture causes death within 3 hours.

During that time several interesting observations can be made. The digitalis action becomes pronounced, at the end of 2 hours, the fish is no longer able to swim straight but leans to one side and as the digitalis action increases to the point of approaching death he begins to lean on the side more and more until death takes place and the fish completely turns over on the side

From studying different standard tinctures it was found that some, in the first hour, produced a very extensive catharsis, but that some others did not show this action of digitalis on smooth muscle fibres.

These results are very interesting inasmuch as we tried to ascertain to what fraction of the digitalis glucosides it was principally due. Digitalin was tested and while its action was very prompt in producing the stunning of the fish and the swimming on the side and death within 3 hours, or less if the dose was greater than 5 mgs., no catharsis was noted.

Digitalin of commerce, which is a mixture of digitalis principles, mostly digitoxin, also showed very little, if any, catharsis, and while highly potent in producing death within a certain time, according to the size of the dose, the tonic action on the smooth muscle fibres was not produced. We then separated the gitalin faction from the digitalis and found that this glucoside possesses the tonic action on all smooth muscles, evidenced in the gold fish by extensive catharsis, and that very large doses of gitalin are required to produce death. It was necessary to use three times the tincture dose to produce death with gitalin.

Very interesting is the action of strychnine on gold fish. Two milligrams of strychnine in 500 c.c. of water will produce death of the gold fish in about 2 hours, with extreme opisthotonus. At death the fish is twisted to almost a full curve. Before death supervenes tonic and clonic contractions of the entire body are noticeable. The convulsive movements increase until death supervenes.

The Gold Fish in Immunity Studies. The use of gold fish for studies of immunity and of the potency of toxins and antitoxins has been a source of great satisfactcion and interest.

We have found that in treating a gold fish of a gram and a half in 500 c.c. of water with a diphtheria toxin tested in guinea pigs to a definite lethal dose for a 250-gram guinea pig, the lethal dose per gram of animal weight is the same per gram weight of gold fish and water. This method, in addition to giving more readily controlled tests, eliminating the great variation to which guinea pigs are subject—the possibility of disease, dietary disturbances, etc.—appears to be very superior, and at least an excellent corroborative and collateral method for ready use in research laboratories.

Having established the points above mentioned, we attempted to see if it were possible to induce antitoxic immunity in the fish. Accordingly, fish have been treated with sub-lethal doses of diphtheria toxin for 24 days. At the end of 14 days, and after a period of rest of 2 or 3 days, doses 8 to 10 times the lethal dose have been administered without killing the fish, thereby demonstrating the development of antitoxin production in the gold fish. The availability of the gold fish as a laboratory reagent in the study of toxins and antitoxins opens up great opportunities in the purification studies of antibodies, making it possible for the worker to obtain fairly close results first and then submitting his final product to animal tests.

In the study for the purification of diphtheria and tetanus antitoxins where the bio-chemist would make from 200 to 300 derivatives with the protein structure thoroughly changed, the gold fish method would offer to him a very splendid method of estimating the amount of antitoxin loss in the various chemical manipulations when he had arrived at a satisfactory product, then resort to guinea pig methods for potency determination. Thereby he would have a double check on the potency titration of the purified antitoxin.

Summary and Conclusion. The assay on gold fish, of glucosides, alkaloids, poisons and antitoxins affords an excellent laboratory method of extreme accuracy and which is more easily controlled and more economical than any other method of physiological assay in vogue.

In the studies of the various digitalis glucosides, it can give a better method of establishing lethal dose per gram of weight than any method known, in addition to furnishing evidence of physiological difference between various glucosides.

The method of physiological standardization of pure digitalis glucosides on gold fish is not advocated as an absolute substitute for the frog heart method and the guinea pig method of assay but as a double check of extreme accuracy which will serve to pick out any pitfalls in the other tests. The gold fish tests for potency of toxins and the antitoxins opens up new avenues of research to the biological chemist in the work of purification of antibodies and elimination of anaphylactogenic and serum sickness producing proteins.

RECORDS OF INDIANA DRAGONFLIES, VI, 1931

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These records have been compiled from collections of dragonflies made in Indiana during 1931 and identified by E. B. Williamson or the author, and from a few specimens collected in other years but not previously reported. All earlier records have the year indicated, but records from 1931 have usually only the month and day indicated.

About 875 specimens, representing 53 species were included in these collections. Records from Allen, Huntington, Miami, Steuben and Wells counties were furnished by Mr. Williamson who was assisted in the field by Eli Captain, Norman Shufelt, and W. H. Ditzler. Specimens have been furnished to the author by G. Walker Daubenspeck from Fayette, Fulton, Henry, Lake, Rush and St. Joseph counties, by A. W. Trippel from Marshall and St. Joseph counties and by R. R. Heaton from Rush county. A small exhibit collection made by the Nature Guide Staff at Turkey Run State Park, Parke County, was examined during the summer and records based upon this material are followed by the initials "T. R." Records based upon specimens collected by students at the Purdue Forestry Camp at Henryville, Clark County, are indicated by the initials "P. U." Records from Clark and Parke counties, unless indicated by such initials and from all counties not listed above are based upon collections made by Esther Barrett Montgomery and the author.

All new county records, even of the most common species, records of rare or interesting species, and notes on habitats or associations have been selected for publication. Much collecting was done during the season in parts of the state not previously visited by dragonfly collectors and many new county records were thus obtained. One species new to the state list, *Enallagma basidens* Calvert, is recorded, bringing the Indiana list of dragonflies to 132 species.

Attempts were made during the summer to visit as many as possible of the localities which have been described or discussed in detail in previous papers.[1] The water supply reservoir at Oakland City was visited by R. Boner Barrett and the author June 14. About an hour was spent at the lake but very few dragonflies were seen. A male each of *Tetragoneuria cynosura* Say, and *Perithemis tenera* Say, two males and a female of *Ischnura verticalis* Say and a female of *Celithemis elisa* Hagen were taken; *Epicordulia princeps* Hagen and *Tramea sp.*, were seen. The author visited this locality again August 9 and captured three females of *Celithemis eponina* Hagen, the only species seen.

Robert W. Montgomery and the author visited Footes Lake from about 3:30 to 4:30 p. m., July 18. The water was very low, the water margin being from 100 to 300 feet from the usual shore line. In places, this exposed lake bed had grown up with weeds to within 25-50 feet of the water, but in other places farm animals had access to the lake and this exposed margin was bare. Two species, *Plathemis lydia* Drury and *P. tenera* were very abundant, the latter was especially common in the weedy margin of the lake bed and at the edge of the water. At a place where the limbs of a fallen tree extended into the water many individuals of *Argia apicalis* Say were seen and several were taken. Trameas soared over the margin of exposed lake bed and nearby fields and a few Pantalas were seen in the fields. A few Gomphines were seen in the vegetation and on the ground or rocks at the very edge of the water. No Macromias were seen at the lake but a few were flying in lanes and open areas in the woods back from the lake. *M. illinoiensis* Walsh and at least one other species were represented, but *M. taeniolata* Rambur, which has been found at the lake in considerable numbers in other years, was not seen. Butterflies of several species were common, but no mayflies were seen.

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[1] Proc. Ind. Acad. Sci., *29*: 99; *34*: 383; *36*: 287; *38*: 335; *39*: 309; *40*: 347.

The order and numbers used in Williamson's annotated list[2] are followed here.

1. *Agrion aequabile* Say. **Steuben Co.**, Pigeon River, Aug. 9, a male and a female, the only ones seen, were taken.

3. *Agrion maculatum* Beauvois. This common species was captured during 1931 in the following counties from which it had not been reported previously: **Daviess, Fayette, Henry, Lawrence, Martin, Miami, Monroe, Montgomery, Morgan** and **Rush. Parke Co.**, (T R).

4. *Hetaerina americana* Fabricius. **Daviess Co.**, stream near Washington, June 15; **Fayette Co.**, Williams Creek, Aug. 5, 7, Sept. 13; **Miami Co.**, Eel River Aug. 2, very common; **Parke Co.**, (T R); **Rush Co.**, Flat Rock Creek, Aug. 6; **St. Joseph Co.**, swamp seven miles south of Mishawaka, June 13.

11. *Lestes rectangularis* Say. **St. Joseph Co.**, near lake at Lakeville, Aug. 10, 11.

13. *Lestes unguiculatus* Hagen. **Fayette Co.**, Williams Creek, Aug. 5; **Lake Co.**, dry marsh east of and pond west of Merrittville, Aug. 12; **Marshall Co.**, Donaldson Lake, June 25.

14. *Lestes vigilax* Hagen. **St. Joseph Co.**, lake, Notre Dame, Aug. 11.

15. *Argia apicalis* Say. **Clark Co.**, July 15, 17, 20, (P. U. and B. E. M.); **Lawrence Co.**, many localities, July 3 to Aug. 20; **Miami Co.**, Eel River, Aug. 2; **Parke Co.**, pond near Rockville, July 6; **St. Joseph** Co., Leeper Park, South Bend, Aug. 10.

16. *Argia moesta* Hagen. **Lawrence Co.**, several streams near Bedford, July 3 to Aug. 20; **Miami Co.**, Eel River, Aug. 2; **Montgomery Co.**, rocky stream near Waveland, July 6; **St. Joseph Co.**, Leeper Park, South Bend, Aug. 11.

17. *Argia sedula* Hagen. **Lawrence Co.**, streams near Bedford, Aug. 2, 18.

18. *Argia tibialis* Rambur. **Lawrence Co.**, many streams, July 3 to Aug. 2; **Miami Co.**, Eel River, Aug. 2; **Monroe Co.**, creek five miles south of Bloomington, June 28; **Rush Co.**, Flat Rock Creek, Aug. 6.

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[2] Uni. Mich., Mus. Zool., Misc. Publ. No. 2. 1917.

20. *Argia violacea* Hagen. **Fayette Co.**, Williams Creek, Aug. 5, 7; **Lawrence Co.**, near Bedford, July 3, Aug. 2; **Miami Co.**, Eel River, Aug. 2; **Monroe Co.**, creek five miles south of Bloomington, June 28; **Parke Co.**, ponds near Turkey Run State Park and Rockville, July 6; **St. Joseph Co.**, lake, Notre Dame, Aug. 11.

21. *Enallagma antennatum* Say. **Parke Co.**, pond near Rockville, July 6, common.

22. *Enallagma aspersum* Hagen. **Fulton Co.**, pond five miles north of Rochester, Aug. 10; **Lawrence Co.**, pool in sink hole four miles north of Bedford, June 28.

22a. *Enallagma basidens* Calvert. **Gibson Co.**, old water supply lake, Oakland City, July 28, 1929, one male; new water supply reservoir, Oakland City, July 1, 1930, five males. This species was described from Texas and has been known previously, only from the Southwest.

25. *Enallagma civile* Hagen. **Lawrence Co.**, small pool in sink hole four miles north of Bedford, June 28, stream two miles south of Bedford, Aug. 18, 20; **Miami Co.**, Eel River, Aug. 2; **Parke Co.**, pond near Rockville, July 6; **Pike Co.**, pond, Aug. 9; **St. Joseph Co.**, Leeper Park, South Bend, and lake, Notre Dame, Aug. 11. At the small pool in Lawrence County this species was associated with *E. aspersum;* both were numerous; 14 males of *civile* and 11 of *aspersum* were taken.

27. *Enallagma divagans* Selys. **Martin Co.**, stream near Lawrence county line, June 15, five males.

29. *Enallagma exsulans* Hagen. **Daviess Co.**, stream near Washington, June 15; **Fayette Co.**, Williams Creek, Aug. 5; **Lawrence Co.**, streams near Bedford, July 3, Aug. 20; **Martin Co.**, stream near Lawrence County line, June 15; **Miami Co.**, Eel River, Aug. 2; **Rush Co.**, Flat Rock Creek, Aug. 6.

34. *Enallagma signatum* Hagen. **Lawrence Co.**, stream, near Bedford, Aug. 18; **Pike Co.**, pond, Aug. 9; **St. Joseph Co.**, Leeper Park, South Bend, Aug. 10.

41. *Ischnura posita* Hagen. **Clark Co.**, reservoir, state forest, July 15; **Lawrence Co.**, stream, one to two miles south of Bedford, June 22, July 2, 18, 20; **St. Joseph Co.**, Leeper Park, South Bend, Aug. 10. Although taken in many localities during the season, this species was nowhere as common as *I. verticalis*, with which it is usually associated.

43. *Ischnura verticalis* Say. More specimens of this species than of any other are included in the 1931 collections. It was captured in the following counties for the first time: **Clark, Daviess, Fayette, Fulton, Lawrence, Martin, Rush, St. Joseph** and **Washington.**

44. *Anomalagrion hastatum* Say. **Lawrence Co.**, pool in sink hole four miles north of Bedford, June 28, July 21.

45. *Tachopteryx thoreyi* Hagen. **Huntington Co.**, bog, Monument City, June 21. Fifteen males and one female of this rare species were captured at the same locality where it was found in 1929 and 1930. "9:00-11:00 a. m. Saw many more we should have caught. Day bright, hot, sultry, with thunder and rain in the afternoon" (field notes—E. B. W.). One of the males had the head of an ant, *Camponotus herculeanus* (L.) subsp. *pennsylvanicus* De Geer (determined by F. M. Gaige), firmly clamped by the mouthparts to the tarsus of the second

left leg; the remainder of the ant had apparently been chewed off by the dragonfly.

48. *Cordulegaster obliquus* Say. This species was described from Indiana over ninety years ago, but it has been recorded from the state only twice since that time; a female was taken by C. C. Deam at the Forest Reserve, Clark County, June 18, 1920, and four males by E. B. Williamson near Indianapolis, May 27, 1921. Two males were taken during 1931, one each on July 15 and 26, both by M. J. Young, in the same general locality as that of the Deam capture—the state forest at Henryville, **Clark County.** No further data is available for the capture on July 26, but the author accompanied the collector when the specimen was taken July 15. This insect was taken in an open space, about two acres in extent, surrounded by wooded hills. A watercourse, dry at that time except for frequent, small pools of water, passes within a few feet of one corner of the open area. A careful examination of the entire open area and the stream bed revealed no more dragonflies.

68. *Dromogomphus spinosus* Selys. **Lawrence Co.,** stream two miles west of Bedford, Aug. 2, one male with prey, a female *Argia apicalis*, of which the head, prothorax and legs had been eaten; **Miami Co.,** Eel River, Aug. 2, six males and three females.

69. *Dromogomphus spoliatus* Hagen. **Lawrence Co.,** field, Moses Fell Annex farm, July 25, a female; stream two miles west of Bedford, Aug. 2, two males and one female. "The female was seen striking the abdomen against the water near a partly submerged piece of wood, probably ovipositing. A number of Gomphines were seen here today, but only a few Macromias, although previously Macromias had been rather common and Gomphines rare" (field notes, Aug. 2. B. E. M.).

70. *Boyeria vinosa* Say. **Fayette Co.,** Williams Creek, Aug. 4, one male, Sept. 13, five males.

72. *Anax junius* Drury. **Fayette Co.,** Fairview, in a barn lot far from water, Aug. 1, a female; **Lawrence Co.,** pool in sink hole four miles north of Bedford, July 21; **Miami Co.,** Eel River, Aug. 2; **Montgomery Co.,** stream five miles west of Crawfordsville, July 6.

83. *Macromia illinoiensis* Walsh. **Gibson Co.,** Footes' Lake, July 18, a male was taken in a lane through the woods near the lake; **Martin Co.,** near Shoals, July 17, two males; **Miami Co.,** Eel River, Aug. 2, one male. Many Macromias were flying along roads and over open fields about a half mile from White River at the Martin County locality.

84. *Macromia pacifica* Hagen. **Miami Co.,** Eel River, Aug. 2, two males were taken, possibly a dozen seen—flying wild; **Wells Co.,** Wabash River, Aug. 30, a male and a female, the only Macromias seen, were captured by Norman Shufelt, "all dragonflies rare today — saw also *Enallagma exsulans*, many; *E. signatum*, one male; *Perithemis tenera*, two males; and a few Argias" (field notes. E. B. W.).

85. *Macromia taeniolata* Rambur. **Lawrence Co.,** stream two miles west of Bedford, July 13, two males, Aug. 1, four males, Aug. 2, one male; a male flew into the car while I was driving along a road five miles northwest of Bedford, July 29. This species was very numerous at the stream west of Bedford during July and the early part of August. This stream was about 50 feet wide and apparently rather deep; the

banks were high and steep, rock bluffs in places. A narrow growth of trees and bushes lined either bank, but the water was never entirely shaded. There was little herbaceous growth on the banks or in the water; the water was usually muddy. Collecting was done only near a bridge over the stream. Only a few other species of dragonflies were seen here.

87. *Epicordulia princeps* Hagen. **Clark Co.**, reservoir, state forest, July 15, three males.

89. *Tetragoneuria cynosura* Say. **Gibson Co.**, water supply reservoir, Oakland City, July 14, a male.

94. *Somatochlora linearis* Hagen. **Clark Co.**, state forest, Henryville, July 8 to 29. When I visited the state forest, July 23, I saw one or more individuals of this genus along a stream bed of moist sand and gravel with frequent pools of water, but failed to make a capture. Students at the Purdue Forestry Camp reported that dragonflies of this genus frequently flew along the paths and roads at the camp which is not far from the stream bed. The insect collections made at the camp contained fourteen males and eight females of *S. linearis*.

99. *Libellula luctuosa* Burmeister. **Clark Co.**, state forest, July 23 (P. U.); **Fulton Co.**, pond five miles north of Rochester, Aug. 10; **Lawrence Co.**, creek one to three miles south of Bedford, June 18 to August 20; **Miami Co.**, Eel River, Aug. 2; **St. Joseph Co.**, swamp, seven miles south of Mishawaka, June 13, lakes at Lakeville and Notre Dame, Aug. 10, 11; **Washington Co.**, pond along Road 150, July 14.

100. *Libellula pulchella* Drury. **Fayette Co.**, Williams Creek, Aug. 5, 7; **Fulton Co.**, pond five miles north of Rochester, Aug. 10; **Lawrence Co.**, several localities, June 12 to Aug. 2; **Miami Co.**, Eel River, Aug. 2; **Parke Co.**, (T R); **Rush Co.**, Rushville, June 19, 21, 1930.

104. *Plathemis lydia* Drury. The following new county records for this species were made in 1931: **Clark, Fayette, Fulton, Lawrence, Martin, Miami, Rush** and **St. Joseph.** Many individuals of this species, both males and females, were noted along a roadside west of Lafayette, apparently far from water, July 4.

105. *Perithemis tenera* Say. **Lawrence Co.**, pond near Mitchell, July 27; **St. Joseph Co.**, lakes at Lakeville and Notre Dame, Aug. 10, 11; **Washington Co.**, pond along Road 150, July 14.

107. *Erythemis simplicicollis* Say. **Fulton Co.**, pond five miles north of Rochester, Aug. 10; **Lawrence Co.**, creek one mile south of Bedford, July 3; **Marshall Co.**, Donaldson Lake, June 25; **Rush Co.**, Rushville, June 21; **St. Joseph Co.**, lake, Notre Dame, Aug. 11.

109. *Sympetrum corruptum* Hagen. This species was common in the vicinity of West Lafayette about April 10-15, and was found at a wet weather pool at Bluffton, April 13.

111. *Sympetrum obtrusum* Hagen. **Marshall Co.**, Donaldson Lake, June 25, four males and two females.

112. *Sympetrum rubicundulum* Say. **Fayette Co.**, swamp near Williams Creek, July 15, Aug. 5, 7, Sept. 13, common; **Gibson Co.**, Oct. 1, 1930; **Lake Co.**, dry marsh three miles east of Merrillville, Aug. 12; **Marshall Co.**, Donaldson Lake, June 25; **Rush Co.**, Rushville, June 21, 30, 1930.

113. *Sympetrum semicinctum* Say. **Fayette Co.**, Williams Creek and swamp, July 15, two males; Aug. 5, six males, one female; Aug. 7, seven males.

114. *Sympetrum vicinum* Hagen. **St. Joseph Co.**, lake at Lakeville, Aug. 11, two males and three females, all teneral; **Washington Co.**, pond along Road 150, July 14, one female.

115. *Pachydiplax longipennis* Burmeister. **Fulton Co.**, pond five miles north of Rochester, Aug. 10; **Lawrence Co.**, creek one mile south of Bedford, July 3; **Parke Co.**, (T R); **Rush Co.**, Rushville, June 19, 21, 1930; Flat Rock Creek, Aug. 6; **St. Joseph Co.**, Leeper Park, South Bend, Aug. 11; **Washington Co.**, pond along Road 150, July 14.

118. *Celithemis elisa* Hagen. **St. Joseph Co.**, lake at Notre Dame, Aug. 11, six males.

119. *Celithemis eponina* Drury. **St. Joseph Co.**, lake at Notre Dame, Aug. 11, one female.

121. *Pantala flavescens* Fabricius. **Lawrence Co.**, orchard near Orleans, Aug. 21.

122. *Pantala hymenaea* Say. **Jennings Co.**, near North Vernon, driven into car by wind, Aug. 6; **Lawrence Co.**, orchards and ponds, June 8 to July 28; **Miami Co.**, Eel River, Aug. 2, "several males seen over river" (E. B. W.). Pantalas and Trameas were frequently seen in orchards, around ponds and along roads in many parts of the state.

124. *Tramea lacerata* Hagen. **Lawrence Co.**, orchard near Bedford, June 9.

125. *Tramea onusta* Hagen. **Gibson Co.**, Footes' Lake, July 18, one male; **Lawrence Co.**, small pool in sink hole four miles north of Bedford, June 28, a pair flying tandem, and July 21, a male; temporary pond near Bedford, July 22, a male.

ICHTHYOPHTHIRIASIS AMONG THE FISHES OF A POND IN INDIANAPOLIS

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During late winter and the spring of 1931 an epidemic swept through the fishes in the pond located on the South Grove golf links course, Riverside Park, Indianapolis. Hundreds of fishes died and for a period of several days conditions at the pond seemed to be such that the entire fish fauna would be killed by the ravages of the disease. The epidemic was caused by the holotrichous infusorian, *Ichthyophthirius multifiliis* Fouquet, an ectoparasitic form which infests primarily the gills and skin of fish. In these places the organisms feed uopn the tissues of the host and grow to be about 0.8 mm. long. The epidermis develops about the parasite a thickening which shows as a distinct pimple-like spot or pustule that is grayish-white in color. The presence of the parasite may be quite readily detected by the examination of one of the spots or a bit of gill filament under the low power of the microscope. The parasite will usually be found in a steady rotation which is produced by the rapid movement of its cilia. The movement takes place within a cavity where the parasite comes to lie during its development.

The disease, ichthyophthiriasis, has appeared many times in Europe, where it has been found attacking the fishes in freshwater aquaria, fish hatcheries which lacked an abundant supply of running water, and shallow fish ponds. It has been prevalent particularly in Germany, France, and Holland. Several outbreaks of the disease have been recorded in various European publications, but there are only a very few references to it in American literature.

The first record of the disease was that of Hilgendorf and Paulicki (6), who described an epidemic which had appeared in the Zoological Garden, Hamburg, Germany. Their description of the parasite was very incomplete.

In 1876 Fouquet (4) published the results of his study of the disease, which had appeared regularly for a period of ten years in the basins for pisciculture of the College of France. At the end of this time the source of the water was changed and the malady quickly disappeared. The outbreaks commenced about the last of May and lasted until the first of the month of August. He gave a careful description of the adult parasite and, as far as possible, made a study of its life cycle.

Kerbert (8) described a similar disease which had appeared in the Amsterdam aquarium. He named the parasite *Chromatophagus parasiticus*. This parasite was later shown to be the same as the one described by Fouquet.

Neresheimer (12 and 13) worked extensively on the life history of the parasite.

Roth (15) described in detail the activities of the parasite and its effects on the tissues of the host. He also studied its life history.

Buschkiel (1) carried on a number of experiments during which he cultured the parasites on various species of aquarium fishes and observed their activities on the hosts. He also worked out the nuclear changes during the reproductive cycle.

Forbes (3), and Stiles (16) described an outbreak which occurred in the aquarium of the United States Fish Commission during the World's Columbian Exposition at Chicago. The disease very nearly destroyed the trout exhibit for a time. Several other species were seriously infested, but with quite various results. The infection was known to have been introduced into the aquarium by catfish that were brought from the Potomac River, April 28, 1893.

Prytherch (14) described the occurrence of the parasites on fish in the Washington aquarium during the cold winter months. The infected fishes came from Maryland waters and the Potomac River.

Prytherch states that serious epidemics have occurred in various sections of the United States; Davis (2), that the disease is common on pondfishes; and Kudo (9) gives to the parasite a wide distribution; but records which would indicate a widespread distribution of the disease among the American fishes have not been found. Evidently, they were not published.

The parasite has been placed in other genera, and new species have been described which were thought to be closely related to *I. multifiliis.* Later workers considered these forms as synonymous with Fouquet's species. Kudo recognizes one species in the United States.

The disease has been called the "fish louse" disease and the "spot" disease, but these names are confusing, inasmuch as they apply to other fish diseases.

Description of the Pond. The pond where the epidemic occurred is located near the east bank of White River, extending along the east side of Parkway Drive immediately north of Eighteenth Street. The stretch of water is long and narrow, extending for a distance of 1,500 feet in an approximate north and south direction; its width is about 300 feet throughout the greater extent. The water is shallow, the greatest depth being only 4½ feet at the time of the epidemic. At this time the water was of average depth. The bed, which is composed of sand with an admixture of considerable gravel, is covered in most places by a very thin layer of muck; but at the north and south ends the muck becomes a few inches deep. An island is located near the center of the north end.

The pond was formed artificially about thirty years ago when a roadway, which is now known as Riverside Parkway Drive, was built along the east bank of White River and Emerichsville Dam was constructed across the river about one-half a mile below this point. The depression in which the pond lies was made in order to secure material to elevate the roadway above the level of the river bank. Later, when Emerichsville Dam was completed (1900? plans for dam dated February 10, 1899), water was backed up in the river for a distance of two miles. The backwater raised the level of the river opposite the excavated depression and seepage from the river ran into it.

Any fluctuation in the height of the river at this point affects the depth of the water in the pond, but more slowly. Workmen in the park say that three years ago the gates of the dam were opened for a long period of time and the pond dried up to a small puddle. The gates, however, are seldom opened.

Two hundred feet northeast of the north end of the above described pond there is a smaller, oval-shaped pond which is approximately 200 feet long and 150 feet wide. The sides are steep and only a very small part is less than three feet deep. The greatest depth was five feet four inches at the time of the peak of the epidemic. The ground between the two lies two or three feet above the usual water level. When the water is high in the river the two ponds become united. During the flood of the winter of 1930 the ponds were united, but so far as known they have since been isolated. Although no fish died in this pond, some interesting points relative to it came up during the study of the epidemic.

Both ponds are ideal fish ponds and consequently adapted to support a large population. Aquatic vegetation, plankton, crustacea, and insect life are very abundant and furnish large quantities of food; part of the pond is shaded; and the bottom is ideal for nesting. The water is clear. During the epidemic no variation from the normal condition was discovered, and no change is thought to have occurred during the preceding several months.

The ponds were stocked artificially with several species of fishes from the Riverside hatchery, but some may have entered from the river when it was at flood stage.

The hydrogen-ion concentration was taken April 12 at twelve places in the large pond, four in the small one and two in the river opposite the large pond. The Youden pH apparatus was used. The day was clear and warm, and the readings were taken between nine and eleven a. m. The pH range in the large pond was from 7.700 to 7.955; in the small one, 7.955 to 8.006; in the river, 7.870 and 7.785. Water bloom covered about one-fifth of the surface of both ponds.

Extent of the Epidemic. Workmen in the park stated that they had observed a few dead fish the last of February or the first of March. The first reliable report concerning the epidemic came April 8; the author visited the pond April 11 and since then it has been under close observation. Dead and dying fish were found in all parts of the pond. At the north end, the shallowest part, there were more dead fish than elsewhere. The peak of the epidemic was passed about this time. By April 24 only a few fish were dying from the effects of the disease. On May 2 no struggling forms were observed, but several infected forms were seen swimming more or less actively. Shortly after this date no more were observed to be infected; however, none were caught for a careful examination. By May 29 five newly made nests were located and to all appearances the epidemic had ended. Although many fishes survived, as was indicated during the course of the summer, when no fewer than 300 nests were found, the number was reduced to a small per cent of the previous population. The toll of the epidemic was indicated at its close, when 243 dead fishes were found along 60 feet of the east shore. It was estimated that during the epidemic at least two fishes no less than three inches long died for every square rod of surface area.

All sizes of fish from 27-inch carp, 18-inch catfish, 14-inch bass, and 7½-inch bluegills down to last year's hatch died. No species that were known to be present escaped and probably every fish was infected at some time. The latter was indicated April 16, when a 200-foot seine was drawn through the most favorable place and 30 active bluegills and crappies were caught. All were heavily infected.

The following forms were collected and identified according to Jordan's Manual (7): European carp, *Cyprinus carpio*, Linnaeus; channel cat, *Ictalurus punctatus* (Rafinesque); little pickerel, *Esox vermiculatus* Le Sueur; large-mouthed black bass, *Huro salmoides* (Lacépède); green sunfish, *Apomotis cyanellus* (Rafinesque); long-eared sunfish, *Xenotis megalotis* (Rafinesque); bluegill, *Helioperca incisor* (Cuvier & Valenciennes); white crappie, *Pomoxis annularis* Rafinesque. Dried specimens of a species of *Notropis* were found at the close of the epidemic. They probably represented the spot-tailed minnow, *N. hudsonius* (De Witt Clinton).

All species were not equally susceptible. Bluegills, crappies, sunfishes and catfishes seemed to fare the worst. Bluegills, which are extremely prolific, were many times more abundant than all the rest of the species taken together, and this fact made them seem, at times, to be the most susceptible. Large-mouthed black bass seemed to have been the least affected, although some of the dead ones carried very heavy infestations. Grass pike were among the last species to succumb. Their habit of resting near the shore, where most of the dead and dying fish were found, and consequently, where the parasites were more abundant, would subject them to a greater infestation; but the infestation on the dead and dying ones was light. Carp were not present in sufficient numbers to determine their susceptibility, but they carried heavy infestations.

The epidemic may have delayed the nesting period a few days. Under normal conditions the bulk of the bluegills have been observed to nest in this locality between the middle and last of June. The first bluegill nests were made during the last of May. After that date they increased in number until the peak was passed the last of June or the first of July. On July 15, 300 nests (mostly bluegill) were located; 220 had been abandoned and 80 had adults swimming over them. On August 8 eleven nests with males swimming over them were found. On August 15 no more could be located.

Effects of Parasites on Hosts. All soft parts of the skin, mouth, pharynx and gills were invaded by the parasites. The infested fish swam less actively and later became listless. Several observers of the disease in aquaria have reported that the skin became so irritated the fish would attempt to rub off the parasites by swimming against solid objects, but this was not observed in the pond. The gills were deeply inflamed and became bright crimson in color. Where a heavy infection was present, suffocation was indicated by the fish swimming near the surface.

In the later stages of the disease almost all of the fishes were attacked by Saprolegnia. The spores, no doubt, entered through wounds in the skin that were caused by the escaping parasites or through injuries caused by the struggles of the fish. The mould grew rapidly. Some individuals were swimming upright with one-third or more of the body covered by masses of the parasitic filaments. Saprolegnia completed the work of destruction that the parasitic protozoan had begun. The fish gradually lost their equilibrium, swam irregularly in curves near the shore, and slowly died.

Saprolegnia was so abundant on most of the infected fish that casual observers attributed the epidemic to it. It caused the production of characteristic red blotches or "scalded areas," usually on the sides of the body opposite the viscera, and the loss of scales. In some individuals the pectoral and anal fins were nearly destroyed, and frequently the soft parts of the anal, dorsal and caudal were badly affected. But all sorts of combinations of effects and extent of the growth of the fungus were seen.

The external protozoan infection was the heaviest while the fish were still active and before growth of the mould had begun. Many fish died with the skin containing practically no parasitic protozoans visible to the unaided eye, but an examination of the gills revealed an abundance of them.

The Life Cycle of the Parasite. To understand the causes and methods of control of the disease it is necessary to know the life cycle of the parasite. The cycle is rather complicated and it is not typical of the Infusoria in that the adult undergoes a process of sporulation. This process occurs after the adult has escaped from the host and during encystment. Encystment ends in the production of the reinfecting forms.

The Adults. The adults are readily recognized by a microscopic examination of a bit of the infected tissue which has been mounted under a coverslip. Here they may be seen in active rotation. The body is plastic and conforms to the shape of the cavity in which it lies—elongate, oval, globose, somewhat flattened, etc. It is easily released by the use of dissecting needles, or hundreds of free swimming forms of various sizes may be secured by placing an infected fish in a jar of pond water. They swim actively back and forth and when a large number is observed in a jar of water they appear to the unaided eye very much as a group of paramoecia. They are positively phototropic and collect within a short time on the side of the jar next to a north light.

The larger adults measure 0.48 by 0.80 mm. in length, but many smaller ones escape and undergo sporulation. The body is covered by a great number of uniform cilia arranged in a number of regular rows. The mouth is small and is seen with great difficulty in living specimens if at all; but its position may be determined in small adults by the presence of a small irregular mass of recently ingested food and by its anterior position when the animal is swimming. The cytoplasm is granular with scattered opaque spots. Near the center is a large macronucleus. The micronucleus cannot be seen in the adult. A number of small contractile vacuoles are located next to the periphery. The structure of the cortex cannot be seen in the living form. If it is punctured and the cytoplasm permitted to run out, the posterior half of the cortex is seen to be greatly thickened. Prepared cross-sections show this region to be highly specialized. It is thought to serve as an adhesive organ, for loosening epithelium in the food-getting process, and for moving through the tissues of the host.

When the parasites first penetrate the host they are very small. At that time they may feed upon body fluids. Later they feed upon epithelium and blood cells. The cytoplasm of those found in the gills is filled with blood corpuscles. Cross-sections of the gills show the corpuscles entering the cytoplasm through the mouth, which becomes greatly enlarged while the organism is feeding. It is probable that this method of feeding does the greatest damage to the fish.

Encystment and Sporulation. After the parasites escape from the host they swim around for a time, settle down, and form a temporary gelatinous cyst around the body outside of the cilia. Binary fission may take place while the adult is actively swimming, or it may occur after the individual becomes inactive. Frequently, it does not take place.

Within the temporary cyst sporulation begins. Division is regular forming 2, 4, 8, 16, etc., cells until 1,200 to a few thousand small daughter cells are formed. The number of daughter cells which are formed depend upon the size of the adult. These then develop within the cyst into free swimming spores. Throughout the process of sporulation the separate cells rotate constantly within the gelatinous cyst, which adheres firmly to its substratum; their plastic structure responding to pressure from every direction.

The larger adults, isolated in depression slides filled with pond water, completed the process of sporulation within a period of 22 to 30 hours when the temperature varied from 66° to 72° F. Immature adults sporulated more slowly. They swam around longer and the cleavages were slower. One specimen 0.14 mm. long remained a free swimming individual for a period of four days and then within 24 hours formed a few spores. Other smaller ones lived as long as six days and then died without sporulating.

As the spores mature they escape from the cyst over a period of about an hour. The escape is made from the gelatinous cyst through small apertures made by the spores. The first ones to mature swim next to the cyst wall touching it here and there as though searching for a weak place. When a suitable contact has been made the anterior end becomes pointed and with the body rotating the organism forces its way through the wall. In so doing it becomes elongate and, frequently, one is seen to be dumb-bell shaped as the anterior end emerges from the wall and the posterior end follows through the constricted opening. Other spores make similar openings or squeeze through those already formed.

In no culture was the cyst found to burst open as Prytherch (14) described. His photographic figures do not show the gelatinous wall and, consequently, the nature of the escape. Neither were any adults found which produced thousands of spores as he described.

Spores within the cyst are spindle-shaped, but after leaving it they become ovoid with the anterior end bluntly constricted. One side which might be considered ventral is somewhat flattened. The spores swim rapidly by the rapid vibrations of long cilia. In swimming they rotate about a longitudinal axis, with the anterior end moving in circles. The movement is in a straight line for a moment when they turn suddenly and dart in another direction, or they may strike some object with considerable force. When observed under low power the movement away from the cyst is seen to be very slow. A macronucleus and a micronucleus are present. The single contractile vacuole was observed to contract eight times per minute at a room temperature of 65° F.

The spores have no mouth or adhesive organ, but it is said that they enter the host by attaching themselves by the anterior end and penetrate the tissue by the rotation of the body.

If no fish are present the spores soon die. Those observed in this laboratory lived as long as 30 hours. At the end of 17 hours they swam less actively and might not have been able to penetrate the tissues of the host at that time.

The parasite cannot live outside of the host's tissues longer than a few days. My cultures indicate the possibility of about one week in some immature adults.

The spores in the new hosts develop rapidly. Buschkiel (1) and Prytherch (14) found that in warm water the presence of the parasites could be seen with the unaided eye six days after infestation. In cold water the period of development becomes longer.

The presence of a micronucleus in the reinfecting spore indicates that a sexual cycle intervenes. Fouquet (4) and Neresheimer (13) were unsuccessful in their search for a process of conjugation. The later author recognized two types of life cycles, but the careful work of Roth (15) and Buschkiel indicated only one. Buschkiel in a detailed study of the life cycle found that autogamy intervenes during encystment. During the process of cleavage a "nebenkern" (micronucleus?) becomes detached from the macronucleus. This divides twice, the daughter nuclei then undergo changes, and fuse in pairs to give rise to the micronucleus of the spore.

Cause and Control. The outbreak of the epidemic can be attributed to overcrowding in a shallow pond. The nature of the life cycle permits a rapid multiplication of the parasites if there is an abundance of hosts, and shallow water increases the opportunity for the spores to find hosts. The epidemic came to an end when the spores could not find hosts. It is not thought that the long period of dry weather that preceded the epidemic had any influence.

It is interesting to note at this time the possible reason for the non-appearance of an epidemic in the small pond which has been previously described. Many fish, mostly bluegills, large-mouthed black bass and sunfish, were known to be in the pond but whether it was overpopulated to the same extent as the larger one could not be determined. The fish in this pond may not have been infected; however, on April 16, before the nature of the disease was known, a seine was taken directly from the large pond where it had been in contact with many diseased fish and used in the small one. As yet, November 18, no signs of an epidemic have appeared. In the deeper water the fish may be able to escape the spores, or the adult parasites may not undergo sporulation.

Inasmuch as the parasite has become established in the large pond a recurrent epidemic may reasonably be expected within a few years. It can be avoided by taking out a number of fish each year, or the pond can be freed of the parasites by seining out all the fish and restocking after a period of time with uninfected ones.

After an epidemic has started among a large group of fishes, some may be saved by placing them in a stream. This may also spread the disease, but many of the parasites will die in the running water before the life cycle is completed. The large volume of water also decreases the possibility of a spore finding a host.

Ponds which have had infected fishes in them should be drained and sprinkled with quicklime if they are to be used for uninfected fish within a short time.

Small numbers of fishes have been treated in various ways in order to effect a cure. Since the parasites are embedded in the skin and gills, chemicals that would kill the parasites would injure the fish. Consequently, the treatments that are used must attack the parasites as they leave the host.

For small groups of infected fish Prytherch (14), has devised a tank with running water in which they are placed until all the adults have escaped. The running water carries the adults away and they fail to complete the life cycle.

Stiles (16), Davis (2), and Mellen (10 and 11) have suggested chemical treatments for small numbers of fishes. They are methods which require a number of treatments in order to effect a cure. The fish are placed at regular intervals in weak chemical solutions that kill the parasites as they escape from the host, but at the same time they do not injure the fish. For trout Davis suggests a three per cent salt solution, or a five per cent solution of aluminum sulphate. If salt is used the fish are dipped in the solution until they show signs of distress; if aluminum sulphate is used the fish should be left in the solution for one minute. The treatments should be repeated daily until the fish are free of parasites. Mellen (11) recommends five drops of two per cent mercurochrome solution to a gallon of water in which the fish are left for a period of five days. The solution should be renewed each day. A stronger solution may be used advantageously. The discovery of the mercurochrome treatment was made by Mr. Wallace Adams of the Steinhart Aquarium, San Francisco, California.

Dr. G. C. Embody, professor of aquiculture at Cornell University, has had considerable experience with the disease in the state of New York. With his permission the following is quoted from a personal letter:

"For trout I like the salt treatment given three or four times. But for goldfish there is nothing better than ten drops of mercurochrome to one gallon of water. The fish must be left in this solution five days in order to eliminate all stages.

"The concentration of ten drops to the gallon of water is too strong for tropical aquarium fishes and probably for young goldfish. On larger goldfish it acts more quickly than the weaker solution and generally eliminates all of the protozoa in three days.

"Also Dr. Hess' (5) solution of one part potassium permanganate to 270,000 parts of water given for two hours on three consecutive days will usually effect a cure."

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BIRDS OF TIPPECANOE COUNTY, II

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This is the second of a series of papers dealing with birds of Tippecanoe County and intending especially to show the changes in the avifauna during the past forty years.

All notes, unless it is stated otherwise, refer to observations made within the boundaries of the county by the writers. Records of the former Purdue Bird Club, the Biology Department of Purdue, D. R. Burtsfield, F. A. Burtsfield, F. C. Dowelbower, Mrs. F. C. Dowelbower, M. W. Gardner, and F. C. Test has also been used, to whom the writers wish to express their thanks for the material contributed. In the list to follow credit is given to the observer for specific records. Particular effort has been made to give only authentic data. There is always, however, an element of uncertainty in all sight records, and such records of unusual note are given only when made by reliable observers and there is no doubt in the minds of the writers as to their correctness.

The following list is incomplete, to be finished later, and follows the order and nomenclature of the 1931 American Ornithologists' Union check-list to which the numbers in parentheses refer.

1. *Gavia immer immer* (Brünnick). Common Loon. (7.) This interesting bird is probably a regular and uncommon migrant along the Wabash River, although the following notes are the only definite records we have of it. There is a mounted adult loon in the Purdue Museum with a label saying that it was killed in 1906 on the Wabash River near Lafayette. Another mounted specimen there, an immature bird, bears the label "Killed on Wabash River, Lafayette, 1913." There are no recent records, though a bird was shot Oct. 31, 1931, just north of Tippecanoe County on Shafer Lake in White County by Arthur Haley (D. R. Burtsfield).

2. *Colymbus nigricollis californicus* (Heermann). Eared Grebe. (4.) On April 30, 1927, a bird, identified as belonging to this species, was seen on Ross's Pond by the junior writer. It was studied for several minutes with low power glasses at a distance of about 100 yards, the yellow "ears" being plainly visible. This sight record is the only one available for the species, thus indicating the eared grebe to be a very rare migrant or accidental species here.

3. *Podilymbus podiceps podiceps* (Linnaeus). Pied-billed Grebe. (6.) Twenty-five years ago this grebe was considered as fairly common, arriving about the last of March. At the present time it is a regular and fairly common spring and fall migrant, flocks of eight to a dozen being often seen. The earliest spring date of arrival is March 25, 1929, when one was seen by D. R. Burtsfield. The main movement is in the first half of April with a few stragglers being recorded for the latter part. The fall migration occurs usually in the latter part of September

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and continuing into November. First and last dates are Aug., 1891 (9 seen by F. C. Test) and Nov. 16, 1929 (1 by D. R. Burtsfield). We know of no records of its nesting here, but it would not be surprising if it is found to do so.

4. *Pelecanus erythrorhynchos* Gmelin. White Pelican. (125.) This species is an accidental visitor. The only record we have for the county is a specimen reported to have been killed on the Wabash River Sept. 29, 1895, by Lon Gardner, a saloon keeper in Lafayette. Louis A. Test talked to Mr. Gardner soon afterward but the bird was not seen. The disposition of the specimen is not known, although a mounted specimen in the Purdue Museum about which we have been unable to get information may be this one.

5. *Phalacrocorax auritus auritus* (Lesson). Double-crested Cormorant. (120.) This bird is a very irregular and rather rare visitor in this locality. There is a mounted male bird in the Purdue Museum with the following label: "Shot in March, 1880, from amid a flock of wild ducks on a bayou of Wildcat Creek in Tippecanoe County, Indiana, by Dan Müeller, who donated same to Purdue University". Another mounted specimen there, either a female or young, was killed on the Wabash River near Lafayette in 1908.

Our only recent records are from the notes of D. R. Burtsfield, who reports the double-crested cormorant from Headley's Lake on Oct. 13, 1928, and Nov. 16, 1929.

6. *Ardea herodias herodias* Linnaeus. Great Blue Heron. (194.) Formerly a "tolerably common" migrant and summer resident (Purdue Bird Club notes, 1904), the great blue heron is now quite uncommon, though regular, as a migrant and almost rare as a nesting bird. The earliest spring date is March 22, 1903, and 1904, the latter part of March and first of April evidently being the usual time of arrival. In the nineties about a dozen pairs nested in the large sycamores and elms on a small island in the Tippecanoe River, on the Van Natta farm north of Battle Ground, but this colony has long been extinct. The most recent breeding record is of a pair which raised their young in 1930 on an island in the Wabash ten miles below Lafayette (D. R. Burtsfield). The birds begin to congregate in August, six being seen at Headley's Lake Aug. 7, 1930, by D. R. Burtsfield, and our latest date is Oct. 19, 1928.

7. *Casmerodius albus egretta* (Gmelin). American Egret. (196.) In the spring of 1890 H. N. McCoy reported seeing one of these beautiful birds in Springvale Cemetery, which is on the outskirts of Lafayette near Wildcat Creek and on a hill above the old Erie Canal. Probably on the basis of this record the species was listed in 1904 as a rare migrant. With the influx of these birds in 1930 a number stopped in Tippecanoe County, from one to fourteen being seen at Headley's Lake between Aug. 7 and Sept. 7 by D. R. Burtsfield and the writers. A pair was observed on the Tippecanoe River at the northern edge of the county (Mr. and Mrs. F. C. Dobelbower), and 17 (Possibly some were litte blue herons.) were reported to F. C. Dobelbower as staying in the old Erie Canal bed near the Wildcat Creek. One was reported at Headley's Lake (R. Jordan) July 20, this year (1931), and was seen by the

writers at the same place on Aug. 2 and 18, and again on Sept. 9, probably the same bird being present during the intervening time. Its status thus seems to be that of a very irregular late summer visitor.

8. *Florida caerulea caerulea* (Linnaeus). Little Blue Heron. (200.) The writers have never observed this bird in the county, but there is one sight record for it. Mr. and Mrs. F. C. Dobelbower report seeing a pair in the summer of 1930 on the Tippecanoe River near Big Rock about 12 miles from Lafayette. Tippecanoe County would seem to be within its range, and it may not be as rare as these records would indicate. It is also entirely possible that a few were in a flock of "white herons" reported seen during the same summer about a pond in the old Erie Canal bed.

9. *Butorides virescens virescens* (Linnaeus). Eastern Green Heron. (201). In former years a common summer resident, this well-known little heron has adapted itself to nesting in small patches of woods and old orchards and has held its own in the struggle for existence. One or more can be seen along nearly every creek in the county during spring and summer. Sets of eggs have been taken May 16, 1895, and May 30, 1898, by L. A. and C. D. Test. It is also a common migrant. The earliest and latest dates are, respectively, April 17, 1902 (O. L. Foster and D. A. Hale), and Sept. 27, 1929 (D. R. Burtsfield). These are probably not far from the usual times of arrival and departure.

10. *Nycticorax nycticorax hoactli* (Gmelin). Black-crowned Night Heron. (202.) Fortunately this gregarious heron has increased in the past 30 years. In 1904 the Purdue Bird Club regarded it as a rare migrant, and now it is probably an uncommon and regular migrant and summer resident. No nests have been located, but having been seen June 8, 1929 (D. R. Burtsfield), July 9, 1931, and all through Aug. and part of Sept., 1930, it seems probable that it nests somewhere in the county. At dusk every day during Aug. and Sept., 1930, a flock of about 30 birds would silently and suddenly appear at Headley's Lake to fish. Our earliest spring date is April 3, 1904 (A. F. Ganier).

11. *Botaurus lentiginosus* (Monlagu). American Bittern. (190.) Due to the small number of suitable habitas in the county this very interesting bird is only an uncommon migrant with the possibility of its breeding here, though we have no summer records. Purdue Bird Club notes for 1904 list it as uncommon and question its breeding here. Spring records are twice as plentiful as those of fall, the first being April 23, 1903 (M. L. Fisher), and the last, May 15, 1923 (M. L. Fisher). The fall dates are Sept. 9 and 14, 1931, and Oct. 19, 1928.

12. *Ixobrychus exilis exilis* (Gmelin). Eastern Least Bittern. (191.) We know of only two records for this secretive bird—May 22, 1904 (A. F. Ganier), and two seen at Ross's Pond by the writers early in May, 1926. Probably this species is more common than this scarcity of data seems to indicate and may be called an uncommon, rather than rare, migrant. The 1904 record bears the notation "uncommon." As with the larger species, there is a possibility of its nesting here.

13. *Cygnus columbianus* (Ord.). Whistling Swan. (180.) Seems to be of rare or accidental occurrence in the county. We have one sight record, only. Nov. 6, 1931, F. A. Burtsfield while hunting ducks at

Headley's Lake saw a large white bird, which he is confident was a swan, feeding on the lake. He watched it for some time and says it was a large white bird, and as it tipped up in feeding he could distinctly see its black feet. As Mr. Burtsfield is quite familiar with water fowl it hardly seems likely that he could be mistaken.

14. *Branta canadensis canadensis* (Linnaeus). Common Canada Goose. (172.) Fairly common migrant in spring and fall, seen mostly in flight. The numbers seen in flight have not decreased greatly in the past 25 years but the birds rarely stop here. On the morning of November 14, 1931, F. A. Burtsfield while hunting at Headley's Lake saw and shot a single goose, which was seen by the writers. In the afternoon of the same day another single goose was seen on the same pond and shot. These are the only recent specimens we know of which have been taken in the county.

15. *Chen hyperborea atlantica* Kennard. Greater Snow Goose. (169a.) Rare migrant. Our only record for this rare Indiana bird is a beautiful mounted specimen on exhibition in the main hall of Jefferson High School, Lafayette. Measurements of this bird by D. R. Burtsfield and F. H. Test indicate it to be of this sub-species. A metal label bears the inscription, "——— shot on Wabash River by Alva O. Reser, Oct. 30, 1922". Inquiry disclosed that it was killed while floating alone on the river about three miles above Lafayette.

16. *Anas platyrhynchos platyrhynchos* Linnaeus. Common Mallard. (132.) This duck is a fairly common migrant but the county seems to be out of its regular line of flight. "Flocks of 50 to 100 were common 30 year ago but recently the flight is in small flocks of six to twenty" (F. C. Dobelbower). Mallards are apt to be found in spring and fall on all streams and ponds in the county. They are not known to nest in the county. There are many more fall, than spring, records. An early spring date is March 12, 1930 (D. R. Burtsfield). Early and late fall dates are October 18, 1930 (F. A. Burtsfield), and December 15, 1928 (D. R. Burtsfield). A female bird with many albino wing feathers was once seen on Headleys' Lake by S. R. Esten and the writers.

17. *Anas rubripes tristis* Brewster. Common Black Duck. (133.) Less common than the Mallard but a few are seen almost every year. "Have decreased 40 per cent in the last 25 years." (F. C. Dobelbower). Seems to be more common in fall than spring. A spring date is March 27, 1931, and an early fall date is September 14, 1931. Birds are frequently seen in October and November, our latest date being Nov. 11, 1931, when four were seen (D. R. Burtsfield). They are not known to breed in this county.

18. *Chaulelasmus streperus* (Linnaeus). Gadwall. (135.) Not a common duck in this county and usually seen singly or in pairs. Estimated it has decreased 30 per cent in the past 25 years (F. C. Dobelbower). It has been killed on Ross's Pond in the past two years. An early spring record is March 15, 1930, and a fall record is October 29, 1928 (D. R. Burtsfield). It is not known to nest.

19. *Mareca americana* (Gmelin). Baldpate. (137.) Not common. Single birds and pairs are observed during the migrations, though flocks of a dozen or so are sometimes seen. They are estimated to have

decreased 25 per cent in the past 25 years, (F. C. Dobelbower). It is not known to breed. There are many more spring than fall dates. All the spring dates are in March. An early date is March 14, 1930 (D. R. Burtsfield). A fall date is September 9, 1931, when two were seen at Headley's Lake.

20. *Dafila acuta tzitzihoa* (Vieillot). American Pintail. (143.) Spring and fall migrant but not very common, though a few are seen each year. Is not uncommon at Headley's Lake and Whitsel's Pond. Spring and fall records are about equal. Large flocks are rarely seen now though F. C. Dobelbower says flocks of 400 used to be common, and estimates these birds have decreased 50 per cent in the past 25 years.

An early spring record is February 28, 1931, and a late record, April 13, 1930. Fall records are August 13, 1931, and November 7, 1928 (D. R. Burtsfield).

21. *Nettion carolinense* (Gmelin). Green-winged Teal. (139.) Migrant in spring and fall. Not common. Not known to breed. Most of the dates are in the fall when the birds are seen in small flocks. A spring date is March 27, 1931, while an early fall date is August 18, 1931. A late date is November 3, 1931. Dobelbower says it has decreased 40 per cent in the past 25 years, but F. A. Burtsfield says it seems to be holding its own.

22. *Querquedula discors* (Linnaeus). Blue-winged Teal. (140.) Spring and fall common migrant, apparently more common in spring. It passes south rather earlier in the fall than most of our ducks. Many of our records are from Headley's Lake. The earliest spring record is March 24, 1929, and the latest April 29, 1925. An early fall record is August 30 (D. R. Burtsfield) and the late date is October 3, 1928 (D. R. Burtsfield). F. C. Dobelbower estimates that these birds have decreased 40 per cent in the last 25 years.

23. *Spatula clypeata* (Linnaeus). Shoveller. (142.) Migrant, rather uncommon, but a few are usually found each year. It has been taken along the old canal near Wildcat Creek.

A spring date is March 27, 1929 (D. R. Burtsfield), and a fall date is Nov. 3, 1928 (D. R. Burtsfield).

24. *Aix sponsa* (Linnaeus). Wood Duck. (144.) Summer resident, never very common. In the last twenty years it has been quite rare but at present seems to be slowly increasing under protection. There are two mounted birds, both adult males, in the Purdue Museum, one bearing a label "Killed 1914 near Lafayette on prairie" and the other "Killed on Wabash River near Lafayette, 1907".

Recent dates are June 28 and 29, 1930 (D. R. Burtsfield), in different localities and September 19, 1931, when a male in full plumage was seen at Headley's Lake.

25. *Nyroca americana* (Eyton). Redhead. (146.) Migrant, usually late in the fall. Now uncommon, though 25 years ago there were large numbers migrating through here (F. C. Dobelbower). It has been taken at Headley's Lake. A male, mounted, in the Purdue Museum has a label which is almost destroyed but has part of the word "Lafayette" visible on it.

26. *Nyroca collaris* (Donovan). Ring-necked Duck. (150.) Migrant, not uncommon. It is frequently found in company with the scaup but usually arrives and leaves somewhat earlier. Only a half dozen or less are seen together at one time. The spring records are more numerous. Early and late spring records are February 21, 1930 (D. R. Burtsfield), and March 27, 1931. Fall records are October 26, 1929, and November 11, 1931 (D. R. Burtsfield).

27. *Nyroca valisineria* (Wilson). Canvasback. (147.) Rare migrant, as this is not in the usual line of migration. Has been shot by F. C. Dobelbower and F. A. Burtsfield, the latter getting two at Headley's Lake in 1929, one November 2 and the other November 16. There are no spring records.

28. *Nyroca marila* (Linnaeus). Greater Scaup Duck. (148.) Regular migrant, apparently not common but probably often confused with the Lesser Scaup. The only definite record is one shot November 15, 1929 (D. R. Burtsfield).

29. *Nyroca affinis* (Eyton). Lesser Scaup Duck. (149.) Probably our most abundant duck. Is an abundant spring and fall migrant but is not known to breed. Flocks of 15 to 40 are commonly seen, usually on one of the ponds. Spring records are the most numerous. The earliest spring record is March 1, 1929, and the latest April 19, 1930. Early and late fall dates are August 20, 1929 (D. R. Burtsfield), and November 24, 1928 (D. R. Burtsfield). F. C. Dobelbower estimates that this duck has decreased 50 per cent in the last 25 years, while F. A. Burtsfield thinks it is holding its own.

30. *Glaucionetta clangula americana* (Bonaparte). American Golden-eye. (151.) Migrant and possible winter resident, seeminly not common as there are only a few records. An early date is January 17, 1931, and a late spring date is March 30, 1931. The only fall record is December 8, 1928 (D. R. Burtsfield). These records seem to indicate that the Golden-eye is a winter resident, probably staying on the swifter streams. A mounted adult male in the Purdue Museum is labelled "Lafayette, Indiana".

31. *Charitonetta albeola* (Linnaeus). Bufflehead. (153.) This duck seems to be a rare spring and fall migrant, and, perhaps, at times a winter resident. There are only two dates, March 17, 1929, and November 22, 1930, both by D. R. Burtsfield.

32. *Clangula hyemalis* (Linneaus). Old Squaw. (154.) This interesting duck is a very rare winter visitor. Our only record is of one D. R. Burtsfield and the junior writer saw swimming among the numerous ice-cakes on the Wabash River just at the edge of Lafayette on Feb. 23, 1929. Several minutes were spent in watching it until it flew downstream.

33. *Erismatura jamaicensis rubida* (Wilson). Ruddy Duck. (167.) Regular but not common migrant; seems to be more frequent in spring as there are few fall records. The earliest spring record is February 28, 1930 (D. R. Burtsfield), and the latest spring record is April 19, 1930. The only fall date is November 3, 1928 (D. R. Burtsfield). A skin of a female taken on a pond near the junction of the old canal and the Wildcat Creek in the spring of 1890 is in our collection. F. C.

Dobelbower estimates this duck has decreased 30 per cent in the past 25 years.

34. *Lophodytes cucullatus* (Linnaeus). Hooded Merganser. (131.) Migrant, not common, and possibly rare winter resident. All records are for late fall or spring. Early and late spring records are March 27, 1931, 4 males and 4 females; April 9, 1926; November 22, 1930 (D. R. Burtsfield) is a fall date. All birds were on the Wabash River, occasionally near town, and singly or in very small groups.

35. *Mergus merganser americanus* Cassin. American Merganser. (129.) Not uncommon winter resident locally. Does not breed. Seems to be particularly common on the Tippecanoe River near the Van Natta farm where it seems to remain during the winter in flocks of from 10 to 50. The earliest fall record is Dec. 27, the birds being seen on this date in both 1929 and 1930. The latest spring date is April 12, 1923, when 24 were reported at Ross's Pond (C. A. Behrens). It is estimated to have decreased 25 per cent in the last 25 years, (F. C. Dobelbower).

36. *Mergus serrator* Linnaeus. Red-breasted Merganser. (130.) Accidental summer visitor. The record for the county is a sight record, June 23, 1930, when a single adult male was seen feeding in the Wabash River in 2½ feet of water, 75 feet from shore, at Ross Camp by D. R. Burtsfield, who studied it carefully for some time. It is probably also a rare migrant and winter resident though there are no records available for it as such.

37. *Cathartes aura septentrionalis* Wied. Turkey Vulture. (325.) Summer resident, but not very common, this county being too near the northern limit of its range. Nests are occasionally found in the county but they are not common, and there have been none reported for a number of years. In the summer of 1902, C. D. Test and the senior writer found a nest with two young under the top of a fallen tree on a ridge between two wooded ravines leading down to the Wabash River just south of the State Soldiers' Home. May 10, 1903, a set of two eggs was collected from the same nest and is now in our collection.

The turkey vultures usually arrive early in March and leave in October. An early spring date is February 28, 1931, and a late fall date October 26, 1929.

38. *Ictinia misisippiensis* (Wilson). Mississippi Kite. (329.) This rather rare bird should perhaps be placed on a hypothetical list, as the only possible record we know for it is the following note published by Amos W. Butler in his "Birds of Indiana". "Mr. Chas. Drury writes me of a speciman of a Mississippi Kite which was sent to him from Lafayette several years ago, which he supposes was killed near that place." We have been unable to obtain more information concerning this record.

39. *Accipiter velox velox* (Wilson). Sharp-shinned Hawk. (332.) Notes by L. A. Test in 1904 say of this species: "Not common; a few seen each year. Not known to breed." Due to its habits, it is probably more common than records indicate, but as we have only two definite dates for the past few years—April 19, 1925, and March 15, 1930—it can be no more than quite uncommon. Probably it is a year-round resident.

40. *Accipiter cooperi* (Bonaparte). Cooper's Hawk. (333.) Notes of 1904 list the Cooper's Hawk as not uncommon and say that it breeds. Our observations of the last few years indicate that it is now rather uncommon, though of more frequent occurrence than the sharp-shinned hawk. No nesting records are known but it almost certainly is a resident.

41. *Buteo borealis borealis* (Gmelin). Eastern Red-tailed Hawk. (337.) Formerly the most common hawk about here, being abundant and breeding commonly, this big bird has suffered from the ignorance of farmers and hunters. It is now barely a tolerably common resident.

42. *Buteo lineatus lineatus* (Gmelin). Northern Red-shouldered Hawk. (339.) As in the case of practically all other hawks this one has decreased considerably in numbers from its former status as a fairly common resident. It is now uncommon, being seen mostly in the winter but probably breeding, at least in small numbers. The cutting off of considerable areas of timber in the past forty years, combined with constant persecution, has played havoc with all of the woods-loving species of hawks.

43. *Buteo platypterus platypterus* (Vieillot). Broad-winged Hawk. (343.) One of the rarest of our hawks now, although formerly it was considered "not common". There are but few records. The skin of a male taken April 19, 1892, is in our collection. The specimen was taken in a rather open tract of woods less than a mile south of West Lafayette.

44. *Buteo lagopus s. johannis* (Gmelin). American Rough-legged Hawk. (347a.) This hawk has been considered rare in the county but a number of records for 1931 seem to indicate that it was common this year, as in many parts of the state. Most of the records are for late winter and early spring.

The following are 1931 dates: January 3, dark phase near Romney; January 4, light phase found dead near Battle Ground; January 15, light phase near Mulberry; January 15, dark phase near Mulberry; February 10, light phase near Mulberry; March 27, dark phase near Lafayette. The skin of a male in the Purdue Museum is labelled Lafayette, Indiana, March 13, 1899. In our collection is a skin of a large and very dark specimen of the black phase captured alive in the southern part of this county or northern part of Montgomery County in the fall of 1905.

45. *Haliaeetus leucocephalus alascanus* Townsend. Northern Bald Eagle. (352a.) This fine bird is occasionally seen and taken in the county but will have to be considered rare. It is of irregular occurrence, mostly seen during the late fall or winter. D. R. Burtsfield reports one near Battle Ground, November 8, 1930, while one was observed by the writers January 4, 1931, along State road 43 at the northern edge of the county. This bird was an adult with the white head and tail. F. C. Dobelbower says eagles were seen in some numbers on the Wea Plains about 1900.

No local specimens are available for measurements but as all our records are for winter it is probable that this northern sub-species is the one seen.

46. *Circus hudsonius* (Linnaeus). Marsh Hawk. (331.) Considered as common thirty years ago, being "seen principally in spring

and summer on the prairies" but not definitely known to breed, this graceful hawk has, most unfortunately, been persecuted as a "hen-hawk" until it is now only tolerably common, as a winter resident. We have no summer records; so it probably does not nest in the county. Single individuals are almost always seen, usually beating back and forth above fields surrounding a pond or a stream. One bird was seen to swoop two or three times at some ducks on Ross's Pond but they paid little attention to him. Most of our marsh hawks have left for their nesting grounds by the middle of March, March 30, 1931, being the latest date. Their appearance in fall is early in August, the earliest available record being Aug. 7, 1931.

47. *Falco sparverius sparverius* Linnaeus. Eastern Sparrow Hawk. (360.) This beautiful little hawk is a common bird in the county and seems to be a permanent resident. It breeds commonly and many are seen during the winter. They frequent the railroads and highways where they are most commonly seen sitting on the telephone poles. It is not uncommon to see them hunting for English sparrows around the buildings on the Purdue Campus.

48. *Bonasa umbellus umbellus* (Linnaeus). Eastern Ruffed Grouse. (300). The authors, personally, have never observed this bird in the county, but it is said formerly to have been a resident. As the forests were cut off and gradually disappeared the ruffed grouse disappeared with them. Undoubtedly the bird nested here but we have no records.

49. *Tympanuchus cupido americanus* (Reichenbach). Greater Prairie Chicken. (305.) Formerly a common resident in the prairie region of the county but now very rare, though probably not quite extinct. In the early nineties it was still fairly common on the Wea Plains near Farmers Institute, and the senior writer has even flushed birds on the Purdue University Campus. A mounted male bird in the Purdue Museum bears the label "Killed near Lafayette, Indiana, 1909".

There are probably still two or three small coveys in the southeastern part of the county. Mr. F. A. Bolteron writes to Mr. Sidney R. Esten under date of February 19, 1930: "* * * a few exist about three miles to the southwest of South Raub on a farm tilled by John Beck. About six years ago this flock numbered 40 birds. Their numbers have been very much depleted lately." F. C. Dobelbower says that six were reported from southwest of Romney in the fall of 1931. The prairie chicken will probably soon be extinct in this county.

50. *Colinus virginianus virginianus* (Linnaeus). Eastern Bob-white. (289.) Formerly was a very common summer resident and almost every farm had a covey or two but now much less common than 30 or 40 years ago. While they are still not uncommon in the county, flocks are now widely scattered and they seem to have become noticeably fewer in the past five or ten years. They are resident and probably do not wander far from the nesting place. In the collection of the writers is a set with 27 eggs taken 10 miles south of Lafayette near Farmers Institute, May 24, 1891. These fine game birds are rapidly growing scarcer, and unless something is done to help give them more protection they will soon become rare in this county.

51. *Phasianus colchicus torquatus* Gmelin. Ring-necked Pheasant. (309.1.) Our only knowledge of this introduced bird is the following, obtained from F. C. Dobelbower. "There have been about 300 released in Tippecanoe County in the last three years. This year (1931) the State released 140 three-fourths grown pheasants. The balance was released by local Waltonians from eggs from the Division of Fish and Game." Dobelbower says that individuals are occasionally seen in the northwestern section of the county. As yet, they have probably had very little, if any, effect upon the county avifauna.

52. *Meleagris gallopavo silvestris* Vieillot. Eastern Turkey. (310a.) Probably formerly occurred in this county but if so has not been seen here for at least 50 years. We have no records, but as Prof. Evermann reports them as common in Carroll County as late as 1870, they probably were also found in Tippecanoe County until about that time.

53. *Rallus elegans elegans* Audubon. King Rail. (208.) Formerly this bird was considered as a migrant, occasionally breeding (F. C. Test). At the present its status seems to be about the same. No nests have been found, but it almost certainly does breed here as it has been seen May 30, and June 15 and 29, 1930, by D. R. Burtsfield, and on July 9, 1931, by L. A. Test, each time at the Willow Pond. Our only other record is of one seen by M. L. Fisher on April 29, 1923. This species is probably more common than the small number of records indicates.

54. *Rallus limicola limicola* Vieillot. Virginia Rail. (212.) This rail also has apparently been little affected in frequency by civilization, seeming to concentrate in the few marshy spots left, and being a tolerably common and regular migrant. Butler writes in his "Birds of Indiana" that it is much more common in spring than in fall. Here, our late records indicate the opposite to be true, although F. C. Test says that formerly it was not an uncommon migrant, especially in spring. Our only spring date is for May 14, 1929, and the early and late fall dates are Aug. 28 and Sept. 25, 1929 (D. R. Burtsfield).

55. *Porzana carolina* (Linnaeus). Sora. (214.) This is the most common of our rails in the county at the present time, although it was recorded as "not common" in 1904. It is noticed particularly in the fall when several may often be flushed in a few minutes at Ross's Pond or Whitsell's Pond. Consequently, we shall term it a rather common and regular migrant, there being here, also, the possibility of its nesting though no nests have been found. Our only spring date is May 5, 1904 (E. C. Salisbury), while those of fall run from Aug. 28 to Sept. 28 (both dates in 1929, and by D. R. Burtsfield).

56. *Gallinula chloropus cachinnans* Bangs. Florida Gallinule. (219.) Up to recently little seems to have been known about the Florida gallinule though F. C. Test listed it as a regular migrant several years ago without giving any specific records. However, there is a mounted specimen in the Purdue Museum labelled "Killed on Wabash River at Lafayette, Indiana, 1910". At the present it is probably still a regular, though little-observed, migrant and occasionally nests.

On May 30, 1930, D. R. Burtsfield located at the Willow Pond a nest of this species containing three eggs. It was built of dead calamus leaves in the form of a platform raised about eight inches above the ground, which was wet but had no standing water on it, and short runways led up to the nest. The nest was placed among the calamus, which completely surrounded the open part of the pond, and about 15 feet from open water. No gallinules were seen on this visit. On June 9, Burtsfield and the junior writer visited the pond, finding the nest in the same condition as before, and located two more nests; one, on the same side as the first and approximately 35 yards from it, contained one egg, and the other, across the open water about 45 yards from each of the others, had eight eggs in it. This latter was perhaps slightly better built than the other two but all were similar in construction and situation. On June 15 there were five eggs in each of the first two nests and still eight eggs in the third. The last visit, by Burtsfield, on June 29 revealed that the first two nests were deserted, perhaps due to the cattle pastured in the surrounding field, and the other contained one dead chick and several fragments of egg shells. On none of the visits were the adult birds seen. During June both of the writers and Burtsfield were out of town, and the nests could be visited only a very few times, unfortunately. From the positions and build of the nests and comparison of the shell fragments with eggs in our collection we think the identification correct.

57. *Fulica americana americana* Gmelin. American Coot. (221.) Considered as a "not common" migrant in earlier years, the coot is at times rather uncommon and in other years, as in 1929, quite common, though seen regularly in spring and fall every year. Migration dates for spring and fall are: March 23 (D. R. Burtsfield) and May 14, 1929, usually arriving about the first of April; Sept. 19, 1929, and Oct. 28, 1928 (both by D. R. Burtsfield). One was seen at the Willow Pond June 9, 1930, by Burtsfield and F. H. Test. Perhaps this bird nested there, although we have no definite nesting records for the county.

58. *Charadrius melodus* Ord. Piping Plover. (277.) Rare migrant. The only record is for Headley's Lake, September 18, 1895. It is possible they have been confused with the semipalmated plover, which is not uncommon at Headley's Lake in the fall.

59. *Charadrius semipalmatus* Bonaparte. Semipalmated Plover. (274.) Migrant, not uncommon in the fall, when it is frequently seen at Headley's Lake with killdeer and semipalmated sandpipers. All of our records are for the late summer. A skin in our collection is from a specimen taken at Headley's Lake September 2, 1929. An early date is August 19, 1929 (D. R. Burtsfield).

60. *Oxyechus vociferus vociferus* (Linnaeus). Killdeer. (273.) Common summer resident and abundant locally during late summer and fall. These birds congregate in considerable numbers at Headley's Lake during August and September. They usually arrive in February and become common in March. In the fall they generally leave in October or early November. The earliest date of first arrival is February 5, 1927, and the latest February 26, 1924 (H. J. Roberts). For the fall the latest date is November 19, 1931.

61. *Pluvialis dominica dominica* (Müller). American Golden Plover. (272.) Rare, though formerly not uncommon during migrations. We have very few definite records. It was reported April 14, 1904, by A. F. Gainer. F. C. Dobelbower has "not seen one since 1908", but F. A. Burtsfield saw a flock in the spring of 1927. It evidently has decreased greatly in numbers in the past 25 years.

62. *Squatarola squatarola* (Linnaeus). Black-bellied Plover. (270.) We have no definite records, but F. C. Dobelbower reports large flocks 30 years ago and while not now common he thinks it has increased some in the past 10 years.

63. *Philohela minor* (Gmelin). American Woodcock. (228.) Migrant and summer resident; formerly common but now rather rare. Woodcock used to nest rather commonly in the county 40 years ago, and there is a set of four eggs in our collection taken April 16, 1890, by F. C. Test in a swampy woods one and a half miles northwest of West Lafayette. Other records are March 28, 1903, and April 7, 1904. A few may still be found about the bayous along the Wabash River. The bird needs special protection if it is not to be completely exterminated in this county.

64. *Capella delicata* (Ord). Wilson's Snipe. (230.) Fairly common migrant and also a rare winter resident as there is one winter record Dec. 26, 1929, but it is not known to breed in the county. It sometimes occurs in large flocks, a flock of 50 being seen April 13, 1929. Our earliest spring record is March 15, 1930, and the latest spring record May 12, 1902 (C. P. Smith). The earliest fall date is August 30, 1930 (D. R. Burtsfield).

65. *Bartramia longicauda* (Bechstein). Upland Plover. (261.) We have few records on the upland plover though apparently it is fairly common during the spring migration, when it is usually seen in large flocks. There are no records of its breeding. The earliest spring date is April 4, 1923 (E. J. Kohl), and the latest April 24, 1929 (D. R. Burtsfield). Several large flocks have been observed in the past year or two by F. A. Burtsfield and F. C. Dobelbower, and they think these birds are more common than a few years ago.

66. *Actitis macularia* (Linnaeus). Spotted Sandpiper. (263.) This well known little sandpiper is a common summer resident throughout the county, where it may be found along any of the streams. It arrives in April and leaves the latter part of September or early in October. The earliest spring date is April 24, 1904 (A. F. Ganier) and the latest fall date, Oct. 5, 1895.

67. *Tringa solitaria solitaria* Wilson. Eastern Solitary Sandpiper. (256.) Migrant, fairly common; may possibly nest. Most of the records are for late summer and fall but it is not uncommon in the spring along ditches and small streams. The earliest spring date is April 25, 1925. In the summer there is a sight record for July 9, 1931, when eight were seen. Other early summer dates are July 13, 1930, and August 2, 1930 (D. R. Burtsfield). The latest fall date is September 28, 1929 (D. R. Burtsfield), and the latest spring date is April 29, 1928 (M. W. Gardner).

68. *Totanus melanoleucus* (Gmelin). Greater Yellow-legs. (254.) Migrant, not very common. Most of the records are for summer and fall when it is not uncommon at Headley's Lake with killdeer and yellow-legs. The only spring record is April 16, 1904 (A. F. Ganier). For summer and fall there are several records, the earliest July 13, 1930 (D. R. Burtsfield) and the latest Oct. 21, 1895, both at Headley's Lake. Skins of specimens taken at Headley's Lake are in our collection.

69. *Totanus flavipes* (Gmelin). Lesser Yellow-legs. (255.) Common migrant, apparently more common during fall migration than in the spring, judging from the records. In August and September they are often quite common at Headley's Lake where with killdeer and pectoral sandpipers they feed on the mud flats. The earliest spring date is July 13, 1930, when D. R. Burtsfield reported it common at Headley's Lake. The latest fall record is October 26, 1929, when one was observed (D. R. Burtsfield). There is no record for its breeding in the county.

70. *Pisobia melanotos* (Vieillot). Pectoral Sandpiper. (239.) Common fall migrant and less common spring migrant. Large flocks are sometimes seen in the spring. It is one of the commonest species at Headley's Lake in the late summer and fall. Early and late spring dates are March 20, 1930, and April 27, 1929. Birds sometimes are seen in midsummer, July 13, 1930, fairly common (D. R. Burtsfield), but are most common the latter part of August through September. The latest date is Nov. 23, 1929.

71. *Pisobia minutilla* (Vieillot). Least Sandpiper. (242.) Migrant, not common; usually seen in the fall. We have no spring records, but it may occur here then. It has been taken at Headley's Lake. The earliest fall record is August 19, 1929, and the latest, September 22, 1929, both by D. R. Burtsfield. On the first of these dates it was reported as common.

72. *Limnodromus griseus scolopaceus* (Say). Long-billed Dowitcher. (232.) Migrant but not common. There are few records for this bird, but it may be more common than it appears. There are but two records for 1930, August 22, and September 3, both for Headley's Lake, and a single individual was seen each time. On the latter date the specimen was obtained and is now in our collection. None were taken in several years collecting at Headley's Lake during the nineties, and it may be the bird is becoming more common. Measurements of the previously mentioned specimen seem to agree more closely with those of this form than the eastern sub-species.

73. *Micropalama himantopus* (Bonaparte). Stilt Sandpiper. (233.) Rare migrant. The only record for the county, which is also the only record for the state, is of a specimen taken at Headley's Lake, Oct. 10, 1892. The skin of this specimen was formerly in our collection but is now in the collection of A. W. Butler of Indianapolis. The identification of the skin was made at the Smithsonian Institution.

74. *Ereunetes pusillus* (Linnaeus). Semipalmated Sandpiper. (246.) Common migrant. Apparently much more common in fall than in spring, as all records for the county are for summer and fall. During August and September it is usually common at Headleys' Lake and along the flats of the Wabash River in company with yellow-legs and Pectoral

Sandpipers. There is no evidence that it breeds here. The earliest summer record is July 13, 1930 (D. R. Burtsfield), when they were reported very common at Headley's Lake. Our latest date is September 20, 1929, also at Headleys' Lake, when one was seen (D. R. Burtsfield). Skins taken at Headleys' Lake are in our collection.

75. *Tryngites subruficollis* (Vieillot). Buff-breasted Sandpiper. (262.) Rare migrant. The only record for the county and the first for Indiana was a specimen shot at Headley's Lake, September 10, 1892. The skin of this specimen is now in the collection of A. W. Butler at Indianapolis.

76. *Larus argentatus smithsonianus* Coues. Herring Gull. (51a.) Formerly, and at the present, herring gulls can be regarded as infrequent regular visitors to this region, being seen at irregular intervals from the middle of February to the middle of April. Usually they are found feeding singly or in twos and threes along the Wabash and Tippecanoe Rivers and at Headleys' Lake, and rarely a small flock will be present.

77. *Larus delawarensis* Ord. Ring-billed Gull. (54.) This smaller species of gull is considerably less common and more irregular here than the herring gull. We have positive records for only five dates, March 28, 1903, Jan. 8, 1927, Jan. 16, 1931, March 28, 1931 and March 29, 1931, a single bird being seen each time; all are sight records. There is the possibility that some observers have mistaken it for the similar herring gull, and thus it may be more common than records show.

78. *Sterna hirundo hirundo* Linnaeus. Common Tern. (70.) This species will have to be listed as a rare visitor as we have only one record for the county. May 22, 1931, a flock of 15 with one black tern was observed in the late afternoon, flying up and down the Wabash River between the Sanitarium and the bridges at Lafayette. They were watched for some time through glasses and there seems to be no question as to the identification. The common tern may prove to be a more frequent migrant than our records show.

79. *Chlidonias nigra surinamensis* (Gmelin). Black Tern. (77.) The black tern has never been a common bird but it is occasionally seen along the river or at some of the ponds in the county. There are a number of records, mostly for late spring and summer. It is not known to breed in the county, but the summer records may indicate that it does so occasionally.

Early and late dates are May 2, 1924, at West Lafayette, and Aug. 30, 1930, when they were reported as common. July 9, 1929, a single specimen was seen by D. R. Burtsfield flying over the Wabash River at Ross Camp, fifteen miles south of Lafayette. The Dobelbowers report two birds near Otterbein, July 6, 1929.

80. *Zenaidura macroura carolinensis* (Linnaeus). Eastern Mourning Dove. (316.) Abundant summer resident and less common winter resident. Most of our doves migrate south in the late fall, but almost every winter a few remain with us, usually in the neighborhood of chicken yards and hog pens. The migrants begin to arrive from the south in February and by the last of the month or early in March are common. An early date is February 16, 1931, and a late fall date is

October 27, 1928 (D. R. Burtsfield). Typical winter dates are December 30, 1920; December 22, 1928, seventy-three seen; December 27, 1929, eight seen; January 3, 1925, fifteen seen. That some of the doves migrate south in early fall is evidenced by the fact that an individual banded at West Lafayette, April 19, 1925, was killed at Cameron, Texas, October 14 of the same year.

They begin nesting early and several broods are usually raised in a season. Nests have been seen with the brooding female surrounded by snow. One early date is April 17, and an extremely late date September 21, 1926, when young left the nest. Doves seems to be increasing rather than decreasing.

81. *Ectopistes migratorius* (Linnaeus). Passenger Pigeon. (315.) Formerly abundant in this county during the migrations, as they were throughout all of Indiana, but now for many years extinct. Some may possibly have nested in the county. Forty years ago they were rare migrants. Our last authentic record for the county is of a young male shot September 8, 1892, in the low, more or less wooded country two miles northwest of West Lafayette, known as the "Swamp." This bird, which was alone, was shot by C. D. Test and the senior writer. It seemed to be tired and was easily approached, flying only from one limb to another of the same tree when frightened. The skin is in the collection of the writers.

82. *Coccyzus americanus americanus* (Linnaeus). Yellow-billed Cuckoo. (387.) This species is a regular summer resident, though somewhat uncommon due to cutting off the heavy timber. Its notes are distinctive, but secretive habits make it quite easily overlooked. The birds arrive from the south usually in May, at times early, and at other times late, in the month. Our earliest date is May 7, 1903 (M. L. Fisher and C. P. Smith). Records of its fall departure are very scarce, October 13, 1896, being our only late fall date.

In our egg collection is a set of six eggs taken by C. D. and L. A. Test near Lafayette, July 8, 1890, and another set of three taken here June 12, 1891.

83. *Coccyzus erythropthalmus* (Wilson). Black-billed Cuckoo. (388.) Our scarcity of records indicates that the black-billed cuckoo is a very uncommon summer resident, though probably quite regular. It certainly is considerably less common than the yellow-billed cuckoo. The spring arrival is evidently at the same time as that of the more common species, our earliest date again being May 7, 1897. The only fall record we have is September 2, 1929 (D. R. Burtsfield), but this is probably not the usual time of departure.

A set of two eggs in our collection was taken here July 11, 1902, by C. D. and L. A. Test.

84. *Tyto alba pratincola* (Bonaparte). Barn Owl. (365.) The barn owl is resident and breeds, but is apparently rather rare. There are occasional reports of this bird, mostly from the southwestern part of the county, but its appearance seems to be somewhat irregular. In the spring of 1890 two young were taken in the county, and in August of the same year an adult was captured alive by F. C. Test, C. D. Test and the senior writer in a maple near the bank of the Wabash River about

a mile south of the Big Four Railroad bridge. This latter bird was kept captive for a year. Its skin is now in our collection. November 10, 1894, one was picked up dead near South Raub and brought to the University by Elmer Waters. April 28, 1923, one was reported by G. L. Hogey of the South River Road.

85. *Otus asio naevius* (Gmelin). Eastern Screech Owl. (373m.) This common little owl breeds and is a resident everywhere in the county, both the red and gray phase being found in about equal numbers. It is found in both town and country, frequently spending the day in barns or in the vines climbing on dwellings. Skins of both color phases are in our collection.

86. *Bubo virginianus virginianus* (Gmelin). Great Horned Owl. (375.) This, largest of our resident owls, used to be fairly common in the county when there were extensive areas of dense woods. As these woods have been cut off the horned owls have become much less common and at present might almost be considered rare. They are residents and breed. The senior writer was one of a party which in March of 1890 took a young horned owl in down from a nest in a hollow of a beech tree in the dense woods one and one-half miles northwest of West Lafayette on the edge of the "Swamp." A. F. Ganier reports a nest with young in the spring of 1905 about five miles west of Lafayette. January 3, 1931, a dead horned owl was found hanging on a fence a few miles south of Lafayette.

87. *Nyctea nyctea* (Linnaeus). Snowy Owl. (376.) This beautiful owl is probably a rare winter visitor in the county. The writers themselves have never seen a specimen in the county. Butler writes of it having been reported from Tippecanoe County, February 20, 1891, by Moffitt. L. J. J. Owens told of having seen one which had been captured alive near Chalmers, just over the White County line, about November 25, 1905. One of the Purdue University students reported seeing one in January, 1906, but this report was not confirmed.

88. *Strix varia varia* Barton. Northern Barred Owl. (368.) The barred owl is a resident, probably rare, for there are very few records. It is a denizen of the deep woods, and as the woods disappear this owl will naturally become less common. The only recent record is that of a recently killed specimen found hanging on a fence five miles north of Lafayette, January 4, 1931.

89. *Asio wilsonianus* (Lesson). Long-eared Owl. (366.) This owl used to be fairly common in the county, particularly in the deep woods of the "Swamp." It was a resident and nested. During the winter, especially, it was common, but we have seen none for some years, and there are no recent records. The clearing of the "Swamp" has probably forced them to other parts.

90. *Asio flammeus flammeus* (Pontoppidan). Short-eared Owl. (367.) This owl was not uncommon in the county, particularly in the "Swamp," thirty-five or forty years ago, but with the cultivation of this land they seem to have become much less common. The records were mostly for the winter months, and they may not have nested. The only recent records are March 15, 1930, when one was seen at Whitsell's Pond by D. R. Burtsfield and F. H. Test, and a dead bird found by D. R.

Burtsfield hanging on a fence near Ash Grove in the northern part of the county.

91. *Cryptoglaux acadica acadica* (Gmelin). Saw-whet Owl. (372.) Probably rare and not known to breed. The only record we have for the county is of a specimen taken in a thicket of small second growth oaks in January, 1890. The skin of this specimen was formerly in the collection of H. N. McCoy and has been given by him to the Richmond (Ind.) High School.

SOME MODIFICATIONS OF LEG STRUCTURE IN THE HYDROPHILIDAE

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This paper has for its main purpose to show some modifications of leg structures in the Hydrophilidae. Thirty-five species were picked from the various sub-families for study. The legs on the left side of the body were removed and mounted on slides. The various specializations were noted and found, in general, to fall in three classes. First, the modifications for aquatic life; second, for terrestrial life, and, third, for a fossorial habitat. Within the family all three types are well shown with intermediate forms. Also within a given genus various sequences of characters may be shown. Only certain modifications will be elaborated upon in this account, particularly the gradation of structural characters from the more or less terrestrial or land-inhabiting type to the aquatic. The Hydrophilidae, as the names of the various sub-groups would imply, are known to be associated with an aquatic habitat, living in or near the water. The family is unique, however, in showing the sequences of modifications for the two widely different modes of life.

CHARACTERS AND HABITS OF THE HYDROPHILIDAE

The Hydrophilidae, or Water-scavenger Beetles, are oval or elliptical, usually blackish beetles, with a distinctly convex dorsal surface. They vary in length from 1.2 mm. to 37 mm. These insects are usually found in or near bodies of fresh water, but are less active swimmers than some of the other diving beetles. When they swim the hind legs are moved alternately, while the Dytiscidae strike with them both together, like a frog. The convexity of the body, the striations, tubercles and irregularities, along with the modifications of the legs, may give an indication of the reason for their inferiority in the swimming method of locomotion. There are some genera having terrestrial habits. These forms live in damp places, in decaying vegetation or in the excrement of herbivorous mammals. The forms, not fitted for aquatic life, have the first joint of the middle and hind tarsi elongated.

In general, the structural characteristics defining the family are as follows: Tarsi with five joints, the first one in many cases so small as to be scarcely evident; the middle and hind legs sometimes having the tibial and tarsal segments compressed and fringed for swimming; the antennae short, of less than eleven joints, not filiform, but consisting of three parts—a basal part of one or two elongate joints, an intermediate part of two or more small joints, and an apical part of larger joints, which are pubescent, the others are bare; the maxillary palpi are often very long; the hind coxae extending the width of the body, nearly or quite immobile.

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CLASSIFICATION OF THE FORMS STUDIED

Hydrophilidae

1. Hydraeninae
    - (1) *Ochthebius rectus* Lec.
    - (2) *Ochthebius holmbergi* Mann.
    - (3) *Hydraena pennsylvanica* Kies.
2. Helophorinae
    - (1) *Helophorus inquinatus* Mann.
    - (2) *Helophorus obscurus* Lec.
    - (3) *Helophorus nitidulus* Lec.
    - (4) *Helophorus lineatus* Say.
    - (5) *Helophorus auricollis* Esch.
3. Hydrochinae
    - (1) *Hydrochus squamifer* Lec.
4. Hydrophilinae
    - a. Berosini
        - (1) *Berosus punctatissimus* Lec.
        - (2) *Berosus miles* Lec.
        - (3) *Berosus aculeatus* Lec.
        - (4) *Berosus subsignatus* Lec.
        - (5) *Berosus exilis* Lec.
        - (6) *Berosus exiguus* (Say).
        - (7) *Berosus infuscatus* Lec.
        - (8) *Berosus striatus* (Say).
    - b. Hydrophilini
        - (1) *Hydrous triangularis* (Say).
        - (2) *Hydrophilus obtusatus* Say.
        - (3) *Tropisternus striolatus* (Lec.).
        - (4) *Tropisternus lateralis* (Fabr.).
    - c. Hydrobiini
        - (1) *Hydrobius fuscipes* L.
        - (2) *Hydrobius scabrosus* Horn.
        - (3) *Enochrus nebulosus* (Say).
        - (4) *Enochrus perplexus* (Lec.).
        - (5) *Enochrus cinctus* (Say).
        - (6) *Laccobius agilis* Rand.
        - (7) *Laccobius ellipticus* Lec.
    - d. Chaetarthriini
        - (1) *Chaetarthria pallida* (Lec.).
5. Sphaeridiinae
    - (1) *Dactylosternum cacti* (Lec.).
    - (2) *Sphaeridium scarabaeoides* (L.).
    - (3) *Cercyon fembriatus* Mann.
    - (4) *Cercyon praetextatus* (Say).
    - (5) *Pelosoma capillatum* Lec.
    - (6) *Cryptopleurum minutum.*

DESCRIPTION OF THE LEG STRUCTURES

Ochthebius. The legs are moderately elongate and appear rather strong. The coxal joints are average size, showing very little modification even in the hind legs. The tibiae are more lengthened, becoming flattened and widened distally. The outer margin and surfaces, particularly the ventral, have spines, which become larger and more formidable along the edge. The tarsal claws are only moderately developed.

The tibial spurs are moderately long in *O. rectus*. The tibial spines are quite numerous, appearing in longitudinal rows on the middle and hind legs. The first four tarsal segments are of about equal length in each of the three pairs of legs, possibly enlarging slightly from the first to the fourth. The fifth tarsal joint is longer than the first four together and a very little wider. There are two or three short hairs arising from between the tarsal joints of each leg. These hairs are about as long as three of the smaller segments.

The tibial spines in *O. holmbergi* are less numerous and scattered, and also shorter than in *O. rectus*. The tarsal fringe, if it can be called fringe, is much shorter in *O. holmbergi*.

Hydraena. This genus, represented by *H. pennsylvanica*, shows even more uniformity in the coxal joints of the three legs than the preceding. The hind coxae are slightly larger and all three are distinctly pubescent, which is also true of the trochanters and femora. The femur of the hind leg has short, blunt spines scattered over the ventral side. The tibiae of the middle and hind legs are long and slender, being straight and somewhat flattened. These segments also have scattered spines and a considerable covering of hair on the middle tibia. The pro-tibial joint has numerous blunt spines located near the distal end. The first four tarsal segments are small, the proximal one exceedingly so. The hairs in the fringe are a little more numerous in this genus than in Ochthebius, and the tarsal claws are slightly longer and more recurved.

Helophorus. In this genus there appears a lengthening of the segments in the three pairs of legs. The front and middle coxae are more or less oval and the hind coxae distinctly elongated, appearing very strong. The femora are quite straight and not enlarged or flattened. The tibiae are slender and straight, with two or sometimes three rows of sharp spines. The anterior tibia is slightly flattened and widened distally. The tarsi are somewhat compressed laterally. The first tarsal segment is small, the second longer, the third and fourth about the length of the second, and the fifth a little shorter than the first four together. The front tarsi have a few scattered short hairs. The middle and hind tarsal joints give rise to a fringe varying in the different species. The modifications of each species will be taken up separately.

Helophorus lineatus

Front tibia—ridged; four rows sharp spines; spurs moderately long.

Front tarsus—first four segments equal in length, fifth longer; two or three hairs.

Mid tibia—three rows of spines, those along outer side longest.

Mid tarsus—first joint short, second longer, third and fourth equal, shorter than second, fifth as long as second, third and fourth; claws moderate; three or four delicate short hairs.

Hind tibia—long, slender segment; four rows of very fine delicate spines—longer distally; spurs moderate.

Hind tarsus—one or two short hairs; two short spines on ventral, distal part of each tarsal segment.

Helophorus inquinatus

Front tibia—flattened; four rows of delicate spines, longer at distal end; spurs short.

Front tarsus—first three equal in length, fifth long; four or five delicate hairs; claws moderately recurved.

Mid-tibia—longitudinal ridges; three rows of delicate spines; spurs longer.

Mid-tarsus—as in lineatus; five or six delicate, short hairs.

Hind tibia—long, slender; four rows of delicate spines; spurs like mid-tibia.

Hind tarsus—proportion of segments as in mid-tarsus; fringe delicate, ten or eleven hairs, long as three segments; claws moderate.

Helophorus nitidulus

Front tibia—flattened, widened distally; four rows of small spines; short spurs.

Front tarsus—segments one, two and three gradually larger distally; sparse hairs, twelve or fifteen; spurs short.

Mid-tibia—four irregular rows of very delicate spines, almost hairlike; spurs moderate.

Mid-tarsus—ventral spines long and fine, almost hairlike; fifth segment with very fine, short fringe.

Hind tibia—flattened, elongate; four irregular rows of delicate spines; spurs moderate, delicate.

Hind tarsus—long, delicate spines; a few delicate hairs.

Helophorus obscurus

Front tibia—spines elongated, fine, almost hairlike on the distal end; spurs short, curved; sparse fine hairs near end.

Front tarsus—four, sometimes five long hairs; numerous short fine hairs; claws longer.

Mid-tibia—four long spines; seven or eight long fine hairs; row of spines along the distal edge.

Mid-tarsus—fine short fringe, a little longer than in nitidulus.

Hind tibia—slender, long, flattened; short spines along the margins; long spurs.

Hind tarsus—fringe of fifteen to twenty hairs, over half the length of the tarsal segments.

Helophorus auricollis

Front tibia—spines delicate along the inner edge, outer margin with blunt spines distally located; five or six hairs; spurs short, recurved.

Front tarsus—two or three hairs; claws moderate; a few very short ventral spines.

Mid-tibia—four rows of fine spines; spurs short, slender.

Mid-tarsus—fringe sparse, five or six hairs, longer than obscurus.

Hind tibia—elongated, spines short, few.

Hind tarsus—fringe long, sparse.

Hydrochus. *H. squamifer*, in general, has leg structures much like the preceding genera. The femora are more elongate and distally enlarged, making the joints appear club-like. The tibiae are slender, with short, blunt spines on the ventral side. The first four tarsal segments gradually lengthen, and the fifth is about the length of the first four. The tarsi, as well as the tibiae, are compressed laterally and between the segments short hairs project dorsally. The tibial spurs are comparatively short and the tarsal claws are long and sharp. There are only very minor differences in the leg modifications in this species and those of some of the forms in the genera, Ochthebius and Helophorus.

Berosus. In this genus there is a lengthening of segments. All the joints have become more slender and graceful. There is little change in the coxa of the foreleg, but those of the middle and hind legs are elongated and widened. They are often pubescent and tuberculate. In most cases there is a distinct protuberance opposite the place of attachment with the trochanter. The femora have a sparse covering of fine short spines or tubercles. The tibiae are of about the same shape in the different species, being slender, straight and slightly compressed. The tibial spurs are of unequal length, the longest being almost the length of the first two tarsal segments. The first joint of the tarsus is small, the second considerably longer, the third and fourth about the length of the second, and the fifth much elongated, usually longer than the preceding four. The tarsal claws are long, slender and sharp, but not as recurved and formidable as the Hydraeninae. In the species of Berosus the bifurcate onychium is very prominent. The spines, fringes found on the tibial and tarsal segments vary in the different species; these will be described separately.

Berosus striatus

Front tibia—three rows of delicate spines, close together; short spurs; ridged slightly.

Front tarsus—six or seven short hairs; modified hairs on the ventral side of the second and third segments in the male sex.

Mid-tibia—four or sometimes five rows of slender sharp spines; no fringes; one tibial spur long and sharp.

Mid-tarsus—short hairlike spines on the ventral side; fringes thick and as long as the tarsus; claws are long, slender, curved moderately.

Hind tibia—fringe half the length of the tibia; outer margin long slender spines; long spurs.

Hind tarsus—fringe as long as tarsal segments; two short spines on ventral side of each segment.

Berosus exiguus

Front tibia—three rows of short spines; very short spurs.

Front tarsus—three or four short hairs; short ventral spines; claws are long, slender; not recurved.

Mid-tibia—two rows of elongate, delicate spines; a fine fringe of hairs, half as long as the tibia.

Mid-tarsus—segments elongated; fringe about half the length of the tarsus; long, slender spines on segments.

Hind tibia—shortened; three or sometimes four rows of spines, thin; short fringe; slender spurs.

Hind tarsus—fringe sparse, almost half the length of the tarsus.

Berosus miles

Front tibia—three rows of delicate spines, sharp, gradually larger distally; spurs quite long.

Front tarsus—two or three hairs; modified hairs on the second and third segment in the male, adhesive sexual hairs; claws long, curved; bifurcate onychium.

Mid-tibia—four rows of fine spines; anterior row heavier, posterior row almost hairlike; long spurs; very fine fringe.

Mid-tarsus—long, dense fringe; longer than tarsus; long ventral spines; long claws.

Hind tibia—three rows of fairly long spines; fringe over one-half length of tibia; thin, slender spurs.

Hind tarsus—fringe almost as long as tarsus; two longitudinal rows of small spines; long claws.

Berosus exilis

Front tibia—two rows of very fine spines; spurs short.

Front tarsus—one or two hairs; short spines on ventral side; claws delicate.

Mid-tibia—delicate, slender spines; a few hairs; long spurs.

Mid-tarsus—longer fringe than tarsus; claws slender.

Hind tibia—a very few slender spines; sparse fringe; large spurs.

Hind tarsus—sparse fringe; hairs about half length of tarsus.

Berosus punctatissimus

Front tibia—elongate; three irregular rows of compact spines; blunt spurs.

Front tarsus—three hairs, sexual hairs on second and third segments; long, slender, recurved claws.

Mid-tibia—long, slender spines, two rows; a delicate fringe; long spurs.

Mid-tarsus—fringe heavy, almost as long as tarsal segments; row of short spines on ventral side; slender, long claws.

Hind tibia—fringe along entire segment; gradually longer distally; one-third length of tibia; three rows of long spines; long spurs.

Hind tarsus—long fringe, length of entire tarsus; slender, delicate claws; moderately long spines on ventral side.

Berosus aculeatus

Front tibia—three rows of spines; very short spurs scattered over the segment.

Front tarsus—three or four hairs; male sex hairs on the second and third segments; long recurved claws.

Mid-tibia—three rows of spines; a few hairs; long spurs.

Mid-tarsus—fringe one-half the length of tarsus; long, slightly curved claws.

Hind tibia—three rows of spines; sparse fringe.

Hind tarsus—short, sparse fringe.

Berosus subsignatus

Front tibia—three rows of short spines, inner row elongated, almost hairlike; blunt spurs.

Front tarsus—few scattered hairs; spines on ventral side fairly long; recurved, slender claws.

Mid-tibia—few, long, sharp spines in four longitudinal rows; long spurs; no fringe.

Mid-tarsus—long fringe; sharp ventral spines.

Hind tibia—long; four rows of long spines; fringe one-third the length of the tibia; long spurs.

Hind tarsus—fairly long, thick fringe.

Berosus infuscatus

Front tibia—three rows of very short spines; blunt spurs, recurved.

Front tarsus—two hairs; sex hairs on ventral side of segment one and two; slender, recurved spines.

Mid-tibia—fairly sharp, delicate spines in four rows; long spurs.

Mid-tarsus—very long fringe, thick, longer than tarsus.

Hind tibia—sharp, irregular spines in four incomplete rows; delicate fringe.

Hind tarsus—long, heavy fringe.

Hydrous. *H. triangularis* has rather sturdy segments, with strong hinge attachments between the coxa and trochanter. The foreleg is comparatively short, being about one-half the length of the middle leg and a little over one-third the length of the hind one. There is a fine pubescence covering the front leg. The middle and hind legs are greatly compressed. The coxal joint is triangular in the former and much elongated and widened in the latter. The femur on the middle leg is shorter and has more spines than the hind leg. The tibiae are about equal in length in the two pairs of legs, but considerably wider and more compressed in the posterior leg. In comparison with other forms previously mentioned, the tibiae have become greatly shortened. These segments, as mentioned before, are covered with short spines irregularly arranged. The longest of the tibial spurs is about one-third the length of the tarsal joints. The tarsi are very much compressed and taper in width from the proximal joint, which is as wide as the distal portion of the tibia to the small, weak tarsal claws. The first small tarsal segment fits diagonally onto the second, which is the longest joint, three times the length of the first. The third, fourth and fifth segments gradually get smaller. There are tarsal fringes on the middle and hind pair of legs; these short fringes are along the entire tarsi.

Hydrophilus. *H. obtusatus* resembles *Hydrous triangularis* very much. The foreleg is proportionately longer, the middle femur elongate, and both tibiae lengthened and with longitudinal rows of spines. The tarsal joints, as well as the tibiae, are compressed laterally and fitted together diagonally as in Hydrous. The fringes are almost one-half the length of the tarsal segments.

Tropisternus. Another genus having leg modifications much like the two preceding forms. Here again the anterior leg is considerably shortened and the last tarsal segment is large with comparatively large recurved claws. The middle coxae of *T. striolatus* and *T. laterallis* are elongate and flattened, being almost as large as the hind coxae. The tibiae have irregular rows of spines, which are short and slender. The outer tibial spur is over one-half the length of the tarsal joint and margined with small spines. The tarsal fringes are not thick, but are over two-thirds as long as the entire tarsus.

Hydrobius. In this genus the hind coxae are extremely long and narrow. The tibiae of the foreleg are compressed and gradually expanded distally. The tibiae are covered with spines, which are short and rather sharp. The tibial spurs of the front leg are gradually recurved outwardly. The tarsal joints are slender and weak, the fifth being the largest. In *H. fuscipes* the tarsal fringes are irregular in length and sparse. *H. scabrosus* has only a few hairs arising from the tarsi. The claws are of moderate length, but comparatively weak.

Enochrus. This group resembles Hydrobius, except the fact that the segments have become slender and more elongate. The tibial and tarsal joints are considerably longer in all three pairs of legs.

In *E. perplexus* the distal part of the middle tibia is widened and compressed. The tibiae have spines and short fringes along the inner margin. The tarsi have scattered short hairs. The first tarsal joint is short, the second a little longer, the third and fourth together the length of the second, and the fifth about the length of the second.

E. nebulosus has the tarsal joints of the foreleg much shorter than other species observed. *E. cinctus* has considerably weakened tarsi, but the fringes are heavy. The tibiae as well as the tarsi are pilose.

Laccobius. This genus has sturdy segments with large, strong coxae in all three pair of legs. The trochanters and femora are short and strong, with a few spines and short hairs. The tibia of the foreleg is almost triangular, heavily spined and recurved spurs. The middle tibia is shorter and densely spined. The hind tibia is elongate and spined. The mid and hind tarsi have a scanty fringe of hairs about half the length of the entire tarsal segments. The claws are well developed. In *L. agilis* the tarsi are almost equal in length, having a heavier fringe than *L. ellipticus.*

Chaetarthria. *C. pallida* has heavy coxal segments and rather large trochanters. The pro-femur is longer than either the mid or hind femora. The mid femur is short and almost oval, the hind a little longer than wide. The front tibia is clubshaped, with the distal portion enlarged and rounded, with short, irregularly arranged spines. The middle and hind tibiae are compressed and spinous. The pro-tarsal segments are very small with a few short hairs. The middle and hind tarsi have five segments with a few short hairs. The claws are small and weak.

Dactylosternum. In the species *D. cacti* the hind coxa is longer than the femur. The three femora are almost alike in size and shape, the anterior being just a little smaller. The tibial segments are compressed and become wider distally. The tibiae are spined in all three pairs of legs, but more distinctly so in the anterior pair. The entire tarsal segments are about one-half the length of the tibia; they are weak and scantily fringed in the middle and hind pairs. The claws are long, but very weak.

Sphaeridium. The species *S. scarabaeoides* has short, stubby segments. The coxa of the foreleg is rounded and heavily spined. On the middle and hind leg the coxal joints are elongate and strong. There is a short but very wide femur in the foreleg. The femora of the middle and hind pair of legs are a little larger. The tibiae are very much expanded, being almost triangular in the middle and foreleg. The hind tibia is more elongate and compressed. Very large, irregularly arranged spines cover the tibiae, increasing in size distally. The tibial spurs are about one-half the length of the entire tarsal joints. The first tarsal segment is long, about one-half the length of the tarsus; the second, third and fourth are shortened, with a little longer fifth segment.

Cercyon. In this genus the coxal joints are lengthened. The femora are all about the same size and length. The tibiae are spined, the protibia having a groove or pocket in the outer side, margined with spines. The tarsal segments bend forward and fit into the groove when the leg is being used for digging. The middle tibia is shorter than the hind; both are compressed and widened distally. The tarsal segments are weak, especially those of the foreleg. There are only a few short tarsal hairs on the middle and hind legs. *C. fembriatus* has heavier tarsal segments than *C. praetextatus*, the latter having more hairs on the middle and hind tarsi.

Pelcsoma. *P. capillatum* has the same general leg structure as Cercyon. There is, however, an elongation of the femora and tibiae. The mid and hind tibiae are slender, with delicate spines arranged in longitudinal rows. The spines are a little heavier in the middle pair of legs. The tibial spurs and tarsal claws are medium in size. The tarsus of the foreleg have very small segments, which fit into a groove in the tibia. There are few hairs on the mid and hind tarsi.

Cryptopleurum. In *C. minutum* there are leg modifications like the two preceding genera. The femora and tibiae are a little heavier proportionately. The tibiae of the middle and hind legs are expanded and spined. The tarsal segments are small and delicate. There are three or four short hairs on the middle and hind tarsal joints. The claws are very weak.

DISCUSSION

The Hydrophilidae are, primarily, terrestrial beetles which have invaded the waters. There are many instances of this occurring in insect life as well as in other animals, a changing from a land to water habitat.

This family shows, in a morphological way, various gradations of structural modifications correlating the insect to the environment. There is not a regular sequence of changes in all the forms. Quite often there are gaps in the development of some particular modification; then again the character may show varying degrees of formation within a given genus.

Since the mode of progression would be one of the most important changes necessary, and associated closely with this are the legs, one would naturally expect these structures to be the ones which would undergo the most noticeable adaptations. Undoubtedly the shape of the body, the roughness or smoothness of the outer parts, would also enter into the modifications for swimming and possibly would be found to account for various irregularities which we find in the sequences of leg structures. For instance, in a group of known good swimmers, we may find the leg modifications quite unlike the type we would expect in so proficient a swimmer—the body convexity or smoothness may compensate for the lack of leg development.

But the leg structures, as will be noted in the description of the various species, show the sequence of specialization from the land to aquatic type.

In general, the modifications are concerned with the middle and hind pairs of legs, particularly the tibial and tarsal segments of these two pairs. The anterior legs are alawys least modified for aquatic life, the principal change being a reduction of size, so they will not be in the way of the other two pairs of legs.

The Hydrophilidae may be roughly grouped into three categories, according to the modification of the leg structures.

The land-inhabiting forms. Dactylosternum and Sphaeridium are of this type. Dactylosternum has long coxae on the hind legs and compressed tibiae, especially in the foreleg. These modifications aid in land locomotion. These forms live in the soft, semi-fluid debris of decaying cacti; the strong femur and sharpened spines on the legs aid in pushing the insect through the mass. Only a few hairs are present on the tarsal segments.

Sphaeridium has large, heavy segments to contain the strong muscular development. These insects live in dung of herbivorous animals and in carrion; they are distinctly scavengers. The strong muscles and the extremely heavy spines covering the tibiae are used to work the animal through the thickened food material. The tarsi are comparatively small, but the claws are large, also an aid in progression.

Another type of land-inhabiting forms are those modified for a fossorial life, exhibited by Cercyon, Cryptopleurum and Pelosoma. The leg structures in these three genera are very much alike, the greatest change being the tibia of the foreleg. This segment is widened with a distinct pocket or groove on the outer side margined with spines. The small tarsi can be bent forward in the groove. This is done when the insects are digging their way through moist debris.

Those feebly developed for swimming will be found in the subfamilies Hydraeninae, Helophorinae and Hydrochinae. There appears a gradual lengthening of segments to a greater or less degree, to allow a wider sweep in movement. The flattening of the tibia and the few spines in Ochthebius suggests a crawling habit in the sediment on the bottom of pools or near the shore. The spines on the tarsi and tibiae are gradually replaced by sparse hairs. A gradation of spines to hairs can be seen especially on the tibial segments of the middle and hind pair of legs. The few hairs are indicative of an aquatic type of locomotion. The fringes are found, first, on the tarsi of the middle and hind legs. Next, the tibiae of the hind legs will bear fringe and, lastly, the mid tibia. These forms cling to aquatic plants, swim poorly, and are unable to dive rapidly. Hydraena, Hydrochus and Helophorus show a loose sequence in the modification of these structures. Helophorus, particularly, shows a gradation in the production and length of hairs. The group includes intermediate forms, having many modifications for the terrestrial life and the beginning of specialization for an aquatic habitat.

The third group comprises those strongly developed for an aquatic habitat and are found in the sub-family Hydrophilinae.

Chaetarthria has heavy, enlarged segments to allow space for the strong muscles used in propelling the insect through the water. The tibiae are flattened and spined, particularly in the foreleg, which would indicate the legs were used to work the body through aquatic vegetation. The tarsal segments are slender and elongated, with only a few hairs. This genus has not developed all the swimming modifications. Hydrobius and Enochrus show a lengthening of the joints, which is an aid in swimming. There is also a gradual increase of the hairs on the tibial and tarsal segments. Laccobius is a good swimmer and accordingly there is a denser, longer fringe on the tarsal segments.

Berosus, Hydrophilus and Hydrous are the best swimmers in this sub-family and in the Hydrophilidae. The forelegs become very much shorter, since they are of very little use in swimming and must cause as little friction as possible. The middle legs lengthen somewhat and the hind leg is very much longer. The hind coxae are long and immobile, giving strength and rigidity. All the segments are compressed, forming a more or less oarlike structure. The tibiae are shortened, because the direction of the movements of the legs in the water does not necessitate as long tibiae as the terrestrial movements do. The tibial spines are reduced and fringes appear, which adds to the effectiveness of the oars. The tibial spurs are long and toothed, probably protective rather than an aid in locomotion. The tarsi on the middle and hind legs become longer than the tibiae, which give a wider, stronger stroke in swimming. The segments are flattened and compressed with sutures diagonal. The flattening adds to the effectiveness of the stroke, and the overlapping of segments gives rigidity to the paddlelike structures formed. There is a gradual twisting of the tarsal segments so the ventral side becomes anterior, offering little resistance as the leg is pulled forward for a stroke. The claws are weakened, also, for the same reason. The fringes are not as long in these insects as in Enochrus and allied genera, since very long fringes would be a hindrance rather than an aid in rapid swimming and diving. The Hydrophilidae have developed within the group very effective leg structures for an aquatic habitat.

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THE PHYSIOGRAPHY OF THE TIPPECANOE RIVER

HERMAN P. WRIGHT

This paper is the partial result of four summers' work in the field. The primary purpose of this investigation was to determine migration routes of the snails into this area and their present distribution. To solve the problems of distribution a very detailed study of the physiography was made. These physiographic results are presented in this paper. The data and conclusions on the distribution of the gastropods are published elsewhere (Wright, 1932).

The Tippecanoe River, in northern Indiana, is one of the larger tributaries of the upper Wabash. It lies within latitude 41-42 degrees, longitude 85-87 degrees. The counties which are partly or entirely drained by it are Noble, Whitley, Kosciusko, Miami, Marshall, Fulton, Cass, Starke, Pulaski, White, Carroll and Tippecanoe. The entire area drained is 1,890 square miles (Scott, 1916). The total length of the river is about 166 miles.

The Tippecanoe River is a consequent stream. Its course is determined by a complicated system of moraines, most of which are assigned to the Saginaw lobe of the late Wisconsin substage of glaciation. The Saginaw-Erie interlobate morainal mass which forms the divide between the Tippecanoe and Eel rivers is termed the Packerton moraine by Malott (1922). The Maxinkuckee moraine extends "northward from the Wabash River some ten miles west of Logansport to the state line north of South Bend. . . . Several small moraines extend nearly at right angles" (Malott, 1922:117) between the Packerton and Maxinkuckee moraines. "These smaller moraines mark the stands of the Saginaw ice-lobes in its retreat northward." Using the names suggested by Leverett (1915:137-139) and Malott (1922:117), those which directly affect the course of the Tippecanoe River are the Rochester, Burket, Bremen, and New Paris moraines.

The great majority of the ninety-five or more lakes of the Tippecanoe River basin lie in depressions of the Packerton morainic system. The swampy and marshy regions of its middle and upper course are remnants of former lakes, many of which have become extinct through artificial drainage.

"The profile of the Tippecanoe River is peculiar in that the fall in the upper course is much less than in the lower course. The greatest fall occurs in the vicinity of Monticello. This is due to the fact that the stream flows over the Cincinnati anticline in northern White County and has been unable to cut through the hard rock at Norway. The Wabash River has been deepening its valley at the mouth of the Tippecanoe faster than the Tippecanoe could deepen its valley in the vicinity of Norway. The result of this condition is a gradually increasing fall in the lower course of the stream." (Tucker, 1922:381-382.) There is

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evidence that the lower course of the Tippecanoe River has been developed later than in the middle course. "It seems probable . . . that from near Ora in Starke County there may have been a northwestward drainage to the Kankakee as well as a southwestward drainage to the Iroquois." (Leverett, 1915:130.)

Because of the marked difference in the upper, middle and lower courses of the Tippecanoe system, it seems best to describe them separately. For convenience in discussion, the upper course is arbitrarily defined as that part of the river basin between the headwaters in Crooked Lake and the point where the river crosses the Fulton-Marshall County line; the middle course, as the area between the Fulton-Marshall County line and the village of Norway in White County; and the lower course, as the region between Norway and the mouth, in northeastern Tippecanoe County.

Upper Course. The Tippecanoe River has its origin in Crooked Lake, near the crest of the Saginaw-Erie interlobate, or Packerton moraine (Malott, 1922:117). A narrow ridge is the "divide" between this and Cedar Lake of the Eel River drainage. The ridge is "a quarter of a mile across and twenty-five or thirty feet high" (Dryer, 1892:164). Scovell (1908:167) discusses the major drainage connections of this region: "Crane Lake and Crooked Lake, through short outlets, flow into Big or Tippecanoe Lake. Goose Lake, New Lake and Old Lake flow into Loon Lake. The outlet of Tippecanoe Lake flows westerly and northerly about two miles, where it joins the outlet of Loon Lake, forming Tippecanoe River. This stream flows northwesterly about five miles into Smalley Lake. . . ." For about two miles below Big Lake and the same distance above Smalley Lake, the stream is swampy. Near Ormas, in Section 24 (T33N, R8E) the river passes through a gap in a low moraine, the axis of which is northeast by southwest. This gap was the site of a former dam which impounded the waters of Big and Loon lakes in the intramorainic valley.

Heriff and Goose lakes (Noble County), tributary to Big Lake, are nearly extinct. Heriff is bordered by a tamarack swamp. The outlet of Goose (Whitley County) into Loon Lake is an intermittent, dredged ditch. The natural outlet of Old and New lakes into Loon is also dredged.

The Gilbert Lake chain, which drains into the north end of Smalley Lake, is composed of six small lakes: Little Metz, Buffalo, Metz, Buckle, Stump, and Gilbert lakes. The entire area of this lake basin is a little more than one square mile. The present open water area of these lakes occupies but a portion of their original basins. These lakes, together with those of the Indian Village chain to the north (Elkhart drainage), lie near the junction of the New Paris and Packerton moraines, which Dryer (1894:26) has distinguished as the Turkey Creek moraine. The gently sloping knolls of this region do not follow any definite course or direction. A low gravel ridge between Buckle and Metz lakes has at some time ponded the waters of Buckle, Stump, and Gilbert lakes into one lake. This low ridge (about four feet in height), through which the present dredged outlet of Buckle passes, now connects these lakes with the Tippecanoe drainage basin. A shallow depression in the middle of Section 10 (T33N, R8E), between Buckle Lake and the swampy Bouse Lake (the upper lake of the Elkhart drainage) was the natural outlet of Gilbert, Stump, and Buckle lakes.

The lakes between Smalley and the swampy "Backwater" of Webster lie near the union of the New Paris and Packerton moraines. The region in western Noble County occupied by these lakes is a mass of ridges, knolls and swampy basins, "a topography which defies verbal description" (Dryer, 1892). Smalley, Johnson, and Baughner lakes, together with smaller lakes of the region, are bordered with swampy tracts. Mill Pond is formed by a dam across the western end of two gently sloping V-shaped ridges. Dryer (1892:101) describes this portion of the Tippecanoe River basin: "The surface resembles that of a sheet of paper which has been wet and dried, the depressions and elevations having very slight relief and no definite boundaries. . . . The marshes are like a platter having only an insignificant depth and no definite margins."

Webster, the "Backwater" with its several smaller lakes, Tippecanoe, Oswego, Stanton, and the Barbee lakes (Sawmill, Plew, Irish, Banning, Shoe, Little Barbee, Kuhn, and Heron) are probably located in outwash from the New Paris and Packerton moraines, according to the interpretation of Leverett. He says (1915:140): "Along the outer or southwest face of the moraine from the Barbee lakes and west end of Tippecanoe Lake to Milford is a gravel plain apparently formed as an outwash from the [New Paris] moraine. . . . A gravelly and sandy tract between the Barbee Lakes and Boydstown Lake [Webster] in eastern Kosciusko County has a northwestward slope that seems to indicate derivation from the moraine of the Huron-Erie lobe [Packerton] which lies southeast of this tract, rather than from the moraine of the Saginaw lobe [New Paris] north of it." A somewhat knolly tract divides the Tippecanoe Lake basin from the Dewart Lake basin of the Elkhart River drainage. The general bearing of this mass of gravelly knoll is to the east, being more prominent north of Webster Lake, and becoming gently undulating in the region of Gilbert Lake in southwestern Noble County. Interlocking drainage is the rule throughout this district.

The lakes tributary to the Barbee group lie on the Packerton moraine. They are Ridinger, Robinson, Rine, Tadpole, Big Cedar, Mud, and Little Mud Lakes. Grassy Creek (Elder Ditch) connects Ridinger Lake with Big Barbee Lake. Its course is roughly U-shaped; it leaves Ridinger Lake from the northwest end, flows north for a little more than a mile through a swampy channel, then swings to the west for about a half mile, then to the southwest for nearly a mile, where it flows through a narrow gap in the morainic mass before it turns to the northwest across a swampy flat to Big Barbee Lake.

After leaving Oswego Lake, below Tippecanoe Lake, the Tippecanoe River is deflected to the southwest by the Bremen moraine. For a discussion of this moraine, see Leverett (1915:137). At Warsaw a northern extension of the Packerton moraine turns the course of the Tippecanoe River again westward. The Chapman Lake basins, south of Tippecanoe

Lake, may be assigned to outwash from the Packerton moraine. Heter Creek is the outlet of the Chapman Lakes. It receives the outlet of Pike Lake before it flows into the Tippecanoe River.

The divide between the Pike and Center Lake basins is a low gravel ridge bearing north-south, less than a mile in length, and a few hundred yards in width. Before the construction of the Moon Ditch "Cutoff" on the Tippecanoe River, which straightened its course, Center Lake discharged its waters directly into the Tippecanoe River. The outlet of Center Lake, since the alteration by artificial drainage, joins the dredged outlet of the Winona and Muskelonge Lake chains outside the city limits of Warsaw. The Bremen moraine abuts the Packerton moraine in the vicinity of Warsaw. The basins of Winona, Pike, and Center Lakes lie within this region. The Winona drainage, including Smith-Guy, Stoller, Stevens, Sherben, Sellers, Tennant, Stafford, and Shelley Lakes, lies on the inner border of the Packerton moraine. The Muskelonge Group (Muskelonge, Carr, Little Carr, Tibbits, and Schultz Lakes), the outlet of which joins the outlet of the Winona chain just west of the city limits of Warsaw, also lies in the northern margin of the Packerton moraine. The latter lake chain lies within that portion of the Packerton moraine which Leverett characterizes as "undulating gravelly, not definitely morainic."

Another small lake chain, consisting of three lakes, Sickle, Hibschman, and Goose, lies in a depression along the northeastern border of the Burket moraine. Goose Lake, the upper lake of this chain, is the only one of the series that has any gravelly shores exposed. The other two are nearing extinction, their shores are low and boggy; the open water area is reduced to small areas, circular in outline. The outlet of these lakes, below Sickle, flows with a scarcely perceptible current through a low flat in a northwesterly direction for nearly four miles before reaching the Tippecanoe River.

The outlet of the Palestine Lake chain joins the Tippecanoe River south of Atwood. This entire lake chain, which includes Palestine, Caldwell, and several smaller lakes, occupies intra-morainic valleys of the Burket moraine. The outlet of Palestine Lake passes through a narrow gap in a ridge of this moraine, about two miles from the Tippecanoe River. Crystal Lake is separated from the Tippecanoe River by a low gravel ridge, drains through an intermittent ditch into the outlet of the Palestine Lakes.

North from the outlet of this series of lakes is anohter intra-morainic valely about four miles in length. Its sluggish stream discharges into the Tippecanoe from a northeasterly direction. The basin of this tributary is scarcely more than one-half mile in width at any point along its course. This valley is bordered on the east by the inner borders of the Bremen moraine, northwest of Warsaw; and on the west by a prominent isolated morainic mass, bearing in a north and south direction. The village of Atwood marks the southern limit of this mass. Leverett (1915:132) does not attribute the Atwood mass to any morainic system. "The features are such as might result from a rapidly receding ice border. . . . It rises about 40 feet above surrounding country, is a mile in length, and nearly one-half mile in width."

The region between the southeastward extensions of the Maxinkuckee and Bremen moraines is very imperfectly drained. Many small, partially drained flats occur in this region. Leverett (1915:132) estimates that "probably one-fourth of the surface" is occupied by them. The largest includes Huffman Lake and the area northwest of it. West of Atwood, the Tippecanoe River meanders through a smaller flat, the greater area of which lies south of the present channel of the stream. It occupies the greater portions of Sections 1, 2, 3, 10, 11, and 12 (T 32N, R 5E). At Tippecanoe Town the river has entrenched a narrow valley in the outwash of the Maxinkuckee and Burket moraines. This narrow valley was the site of a former dam which furnished sufficient water power for a grist mill during the early settlement of this community.

The Yellow Creek group of lakes (Yellow Creek, Mud, Hill, Higgins, Loon, and Beaver Dam Lakes), with their associated swampy areas, is near the inner border of the Packerton moraine in southwestern Kosciusko County. The most eastern of these lakes, Mud and Hill, lie near the base of the Burket moraine. The outlet of this group of lakes, Meredith Ditch, flows northwest through gently undulating drift to the southeastern corner of Marshall County. Leverett (1915:163) considers this area an outwash plain. Here the course of Meredith Ditch is deflected to the southwest by the outer borders of the Burket and Maxinkuckee moraines. It joins the Tippecanoe River near the Fulton-Marshall County line.

Middle Course. The middle course of the Tippecanoe drainage basin extends from the northeastern corner of Fulton County to the village of Norway in central White County. This portion of the river's course is bordered on the south by the Packerton moraine, on the west by the "Kankakee flat," on the north by the Maxinkuckee moraine, and on the east by the outer border of the Burket and an eastern extension of the Maxinkuckee moraine.

The Maxinkuckee moraine, in northern Fulton and southern Marshall Counties, forms a conspicuously knolled topography. The Tippecanoe River flows along the southern border of these knolls through Fulton County. "North of the Tippecanoe River to the vicinity of South Bend occurs a belt of uneven-surfaced drift 5 to 15 miles wide, and attaining in its highest knolls an altitude of nearly 900 feet. . . . The moraine at its outer margin adjacent to the Kankakee plain is prominent, but its inner border is rather indistinguishable from the gentle undulating drift that stands nearly as high as the moraine itself. For some distance south of South Bend the knolls are prominent, rising abruptly 50 or 60 feet above their bases. Sloughs and enclosed basins are numerous, and lakes are plentiful." (Malott, 1922:118.) The basin of Lake Maxinkuckee, in southwestern Marshall County, is at the southwestern border of this moraine. Its inlets from the north and east drain smaller "enclosed basins." One of these basins, about one and one-half miles north of Lake Maxinkuckee, is nearly one square mile in area, occupying the greater part of section 3 (T 32N, R 1E). It is imperfectly drained by tributaries of both Lake Maxinkuckee and the Yellow River. East of this basin are several smaller ones. The Maxinkuckee Lake and Yellow River drainages interlock at several places in this area.

South of the Tippecanoe River, throughout the greater part of its course in Fulton County, is a sand plain. This plain begins southwest of the village of Talma, and extends as a triangular spur southward to near the northern city limits of Rochester. Mill Creek, the outlet of Manitau Lake, flows near the western border of this part of the plain. The northern extension of the Rochester moraine separates the Mill Creek plain from the Mud Creek plain west of Rochester. The sand plain becomes narrow in the vicinity of the junction of Mill Creek with the Tippecanoe River. West of this area the plain extends southward again into the Mud Creek flat. The plain narrows again at Leiters Ford, due to the encroachment of the north and south limbs of the Maxinkuckee moraine. From the village of Leiters Ford westward to the village of Monterey "the plain is on the north side of the river." (Leverett, 1915:137.)

Chippawanuck Creek drains the greater portion of the area lying between the Rochester and Burket moraines. The headwaters of the stream are near the crest of the Packerton moraine in eastern Fulton and southwestern Kosciusko Counties, east of the village of Akron. The stream flows in a northwesterly direction, joining the Tippecanoe River about one mile downstream from the village of Sturgeon.

Mill Creek, the inlet of Manitau Lake, follows the eastern border of the Rochester moraine. This moraine is most pronounced near its northern termination in the vicinity of Rochester, the county seat of Fulton County. A "sharp ridge" bordering Manitau Lake on the west rises to "about 40 feet." The trend of this moraine is to the southeast, until it reaches the village of Macy in northwestern Miami County where it joins the Packerton moraine.

On the west, near the angle formed by the junction of the Packerton and Rochester moraines in southeastern Fulton County, is the Mud Lake basin containing Nyona and South Mud Lakes. These two lakes empty their waters through the swampy Mud Creek into the Tippecanoe River about three miles east of Leiters Ford. The imperfectly drained valley of Mud Creek is nearly four miles wide; it is bordered on the west by the weak southern extension of the Maxinkuckee moraine, and on the east by the outlying sand plains of the Rochester moraine. "On Mud Creek an extensive swamp, standing about 750 feet above sea level, is separated from the Tippecanoe by the sand plain, which seems to form a dam across the lower end of Mud Creek valley. Probably for a considerable period the swamp was occupied by a lake, but the creek had cut its outlet sufficiently deep partly to drain it before the country was settled, and a system of ditches has since much reduced the swamp. The sand of the plains is rather light and drifts in places into dunes, of which the sand ridge along the south border is a conspicuous example." (Leverett, 1915:137.)

"Below Leiters Ford the north side of the Tippecanoe Valley is occupied by a plain three or four miles in extent, which carries fine gravel at its surface. This plain seems to grade into the Maxinkuckee moraine at the north and east borders and was probably formed by direct outwash from that part of the ice border. It remains gravelly only to the outlet of Lake Maxinkuckee. West of that outlet for two or three miles, fine sand lies along the north side of the river. Near Monterey the pitted gravel plain outside the small moraine leading past Bass Lake sets in." (Leverett, 1915:136.)

Near the village of Ora, the Tippecanoe River turns abruptly from a northwesterly to a southwesterly direction. The northwesterly course of the river was maintained to this point by northern and southern portions of the Maxinkuckee moraine and its smaller outlying ridges to the west. The direction of these morainic ridges is northwesterly north of the Tippecanoe River in the vicinity of Ora, and southwesterly south of the river between Ora and Monterey. Between the morainic masses north of the river and the western border of the Maxinkuckee, near Culver, is another sand plain. Leverett (1915:136) considers the eastern portion of this area an outwash plain. "A line of glacial drainage descends westward from the Maxinkuckee moraine just south of Culver station near the west shore of Lake Maxinkuckee to a tamarack swamp around Manitou Lake.[1] Its surface is strewn with cobblestones and small bowlders and is indented by shallow basins. South of it a spur of the main moraine extends west nearly to the Starke County line in secs. 29, 30, 31, and 32, T32N, R1E. From Manitou Lake the water may have discharged either southward along the west edge of the morainic spur to the Tippecanoe Valley or may have continued westward through a gap in the outlying moraine in secs. 23, 26, and 27, T32N, R1W, to strike the Tippecanoe near Ora."

"A ridge connects at the southeast with the Maxinkuckee moraine west of Lake Maxinkuckee, but leads away from it northwestward to Bass Lake in Starke County. It is 1 to 1½ miles wide and seems to mark a position held by the ice before the reentrant between the Saginaw and Michigan lobes had receded to the head of the Kankakee River." (Leverett, 1915:131.) This ill-defined ridge marks the divide between the Tippecanoe and Yellow River drainages. In Section 6 (T 32N, R1 E) are several shallow, broadly U-shaped depressions bearing in a general north and south direction which have the appearance of "sluiceways" between the Tippecanoe and Yellow River drainages.

West of the village of Ora, in southeastern Starke County, the Tippecanoe enters the "Kankakee Marsh" area. "At its point of entry near Ora it is closest to the Kankakee River. From this point the sandy plain slopes northwestward toward the Kankakee as well as southwestward into the territory traversed by the Tippecanoe, forming a very flat alluvial cone. This suggests a spreading of drainage from this part of the Tippecanoe during the height of glacial floods. The present stream for some 25 miles below Ora takes a zigzag course through a series of bowlder-strewn depressions which the sand did not fill and which, as already suggested, may have been occupied by remnants of the ice sheet during the deposition of the sand. The sand on the western side slopes away from the river toward Monon Creek, continuing the southwestward slope it had on the eastern side. Thus Monon Creek, although a tributary of the Tippecanoe, flows through a district lower than that of the main stream. The divide between Monon Creek and the headwaters of the Iroquois is very low and flat, especially south of the Marseilles morainic system, and the general southwestward slope is continued into the Iroquois basin. The valley of the creek, however, is a broad slough which, like the depressions along the Tippecanoe River below Ora, has diverted the drainage to a course out of harmony with the general slope. It seems probable, therefore, that from much of Pulaski County now drained southward, there was a southwestward glacial drainage to the Iroquois and that from near Ora in Starke County there may have been a northwestward drainage to the Kankakee as well as a southwestward drainage to the Iroquois. Below the junction of Monon Creek and the Tippecanoe River there may have been a southward drainage to the Wabash, but if so it seems not to have distributed the sand far in that direction, unless along the immediate valley of the Tippecanoe River." (Leverett, 1915:129-30.)

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[1] Old Manitou Lake. This is not to be confused with the Manitau Lake near Rochester, in Fulton County.

The northern termination of the southern limb of the Maxinkuckee moraine is south of the Tippecanoe River, in the region between the village of Leiters Ford and Monterey. It forms a broad crescent, open to the west, through the western portion of Fulton and northeastern Cass Counties. Leverett (1915:131) describes its course as "southward from the Tippecanoe Valley passing east of south along the east side of Bruce Lake to Kewanna, where it swings around toward Royal Center and runs west of south to the Wabash Valley at Lake Cicott, about 10 miles west of Logansport. From Lake Cicott it is probably continued westward by a line of bowldery ridges past Idaville and dying out east of Monticello. Kawanna stands in a reentrant that apparently marks an incipient separation between the Saginaw and the Erie lobes, for the portion of the moraine to the south conforms more nearly with the trend of a moraine of the Erie lobe lying north of the Wabash than with the moraine of the Saginaw lobe under discussion."

The region bordering the Tippecanoe River through Pulaski and northern White counties is nearly all covered with sand, and has "a nearly plane surface." In many places the sand presents a dune-like topography. In the region east of the Tippecanoe River in Pulaski County sand ridges occur. "There is a somewhat broken east-to-west sand ridge north of Indian Creek in southeastern Pulaski County, which passes through the village of Rosedale (Oak post-office) [Thornhope], where it presents large dunes, and thence turning northeastward, terminates at a gravelly knoll in the northeast corner of T29, R1W. The area from this ridge north to and beyond the middle of Tippecanoe Township [T31N, R1W] is an extensive sandy plain, with the exception of short ridges of sand. There are also the following areas within this plain where sand is not present: (1) a small area in eastern Pulaski County, 1½ miles north of Bruce's Lake; (2) an area south of Bruce's Lake extending south to Little Mill Creek and west about 3 miles from the county line; (3) between Mill Creek and Little Mill Creek; (4) a small area about Star City [T29N, R1W]." (Leverett, 1899:329-330.)

Much of the stream bed of the Tippecanoe between Winamac and Monticello is strewn with bowlders. "The river has a steep slope through this part of its course, the fall from Winamac to Monticello being not less than 100 feet in thirty miles." (McBeth, 1909:341.)

Lower Course. The lower course of the Tippecanoe River extends from Norway in central White County to its junction with the Wabash in northeastern Tippecanoe County. The part of this area north of Tippecanoe County is the margin of the late Wisconsin drift border. The moraines, though not definitely terminal, are probably a detached westward extension of the Packerton terminal moraine of the Saginaw Lobe. About 9 miles north of Lake Cicott[1] a well defined ridge forms the east border of the till plain that descends westward to the Tippecanoe River. This ridge turns abruptly westward near Lake Cicott and is nearly continuous with the Tippecanoe valley at Monticello. For a part of this course the ridge lies along the north slope of a moraine of the Erie Lobe (Packerton of Malott). After crossing the Tippecanoe River at Monticello the moraine turns south, while the ridge continues in a course slightly south of west about to the line of White and Benton counties (Leverett, 1899:329).

The greater part of the area in the vicinity of the Tippecanoe River in southeastern White and western Carroll counties is a ground moraine interspersed with a network of bowlder belts and sandy knolls. This section of the river's course is the only place within the system that the channel reaches bed rock. "It first touches bed rock at Norway, three miles above Monticello. In this part of its course the stream crosses the Cincinnati anticline, whose surface formation in this locality is the hard Niagara limestone. After touching bed rock at Norway, it is near the rock throughout the rest of its course and rock exposures are frequent. The banks below Norway are usually high and there is little overflow. . . . At Monticello the bluffs are 67 feet high and at Oakdale 100 feet. This is approximately the maximum depth of the valley" (Tucker, 1922:373).

South of the village of Springboro, about five miles west of Delphi (T25N, R3W) to the junction with the Wabash River in northeastern Tippecanoe County (T24N, R3W), the Tippecanoe River has eroded a shallow meandering channel in a sand plain.

In the lower course of the Tippecanoe two dams have recently been constructed. The first one at Norway, with a water-head of 30 feet, impounds the waters upstream to the village of Buffalo (T28N, R3W); the other at Oakdale, with a water-head of 40 feet, impounds the waters in the narrow valley to Monticello.

TABLE I

LAKES OF THE TIPPECANOE RIVER SYSTEM

*Artificial Lakes. †Extinct or nearly so.

Lakes	Counties	Township	Range	Section
Oakdale*.........	Carroll............	25N	3W	parts of 3, 4, 33, 34
Shafer*...........	White.............	28N	3W	parts of 21, 16, 17 8, 5, 32, etc.

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[1] This lake is west of Logansport in the Wabash drainage basin.

TABLE I—Continued

Lakes	Counties	Township	Range	Section
O'Brien	Fulton	29N	1E	21
Fletcher	Fulton	29N	2E	parts of 31, 32
Bruce	Fulton-Pulaski	30N	1E	parts of 1, 6
Langhabaugh	Starke	32N	1W	36 S. W.
Hart	Starke	32N	1W	35 S. C.
Leopold	Starke	32N	1W	25 C.
Old Manitau†	Starke-Marshall	32N	1W, 1E	parts of 24, 13, 18
Houghton	Marshall	32N	1E	7 S. W.
Moore†	Marshall	32N	1E	7 C.
Lost	Marshall	32N	1E	28, 29
Maxinkuckee	Marshall	32N	1E	parts of 16, 15, 21, 22, 28, 27, 34
Eddy	Marshall	32N	2E	32 N. E.
South Mud	Fulton	29N	3E	parts of 21, 22, 16, 15
Nyona (North Mud)	Fulton	29N	3E	parts of 16, 15, 10
Manitau	Fulton	30N	3E	parts of 9, 10, 16, 15, 22
Millark	Fulton	30N	4E	31 S.
Rock	Kosciusko-Fulton	30N	5E	parts of 21, 16
Yellow Creek	Kosciusko	31N	5E	27 S.
Higgins (McClure)	Kosciusko	30N	5E	3 N. C.
Loon	Kosciusko	30N	5E	4 N. E.
Beaver Dam	Kosciusko	31N	5E	33 C.
Mud	Kosciusko	31N	5E	26 S. E.
Hill	Kosciusko	31N	5E	25, 30
Huffman	Kosciusko	33N	5E	parts of 31, 30
Crystal (Wooden)	Kosciusko	32N	5E	7 S. C.
Palestine	Kosciusko	31N-32N	5E	parts of 33, 34, 2, 1
Caldwell	Kosciusko	31N	5E	19 N. E.
Sickle	Kosciusko	32N	5E	26 E. C.
Hibschman (Mud)	Kosciusko	32N	5E	25 S. W.
Goose	Kosciusko	32N	5E	25 S. E.
Center	Kosciusko	32N	6E	parts of 5, 8
Muskelonge	Kosciusko	31N	6E	3 N. W.
Fish	Kosciusko	31N	6E	2 W. C.
Tibbits (Downing)	Kosciusko	31N	6E	12 S. W.
Schultz	Kosciusko	31N	6E	22 N. E.
Carr	Kosciusko	31N	6E	parts of 4, 9
Little Carr	Kosciusko	31N	6E	4 S. W.
Winona (Eagle)	Kosciusko	32N	6E	parts of 17, 16, 15, 21, 22
Smith-Guy	Kosciusko	32N	6E	36 N. E.
Stoller	Kosciusko	32N	7E	31 S. W.
Stevens	Kosciusko	31N	7E	4 N. E.
Sherben	Kosciusko	31N	7E	9 N. E.
Sellers	Kosciusko	31N	7E	9 E. C.
Tennant	Kosciusko	31N	7E	10-15
Stafford	Kosciusko	31N	6E-7E	5 W. C.
Shelley	Kosciusko	31N	6E-7E	5 C.
Little Pike	Kosciusko	32N	6E	5 N. E.
Pike	Kosciusko	32N	6E	parts of 5, 4, 8, 9
Little Chapman	Kosciusko	33N	6E	35 C.
Big Chapman (Little Eagle)	Kosciusko	33N	6E	parts of 27, 26, 25, 24

TABLE I—Continued

Lakes	Counties	Township	Range	Section
Oswego	Kosciusko	33N	6E	parts of 11, 12
Stanton	Kosciusko	33N	6E	12 S. E.
Tippecanoe	Kosciusko	33N	6E-7E	Parts of 1, 6, 12, 7, 8, 18, 17
Sawmill	Kosciusko	33N	7E	20-21
Plew (Sechrist)	Kosciusko	33N	7E	parts of 21, 28
Irish	Kosciusko	33N	7E	parts of 20, 29
Banning	Kosciusko	33N	7E	20 C.
Shoe	Kosciusko	33N	7E	intersection of 18, 17, 19, 20
Little Barbee (Kuhn)	Kosciusko	33N	7E	28 N.
Big Barbee (Hammon)	Kosciusko	33N	7E	parts of 28, 27, 34
Dan Kuhn	Kosciusko	33N	7E	27 E.
Heron	Kosciusko	33N	7E	22 S. C.
Ridinger	Kosciusko	32N-33N	7E	parts of 36, 1
Little Robinson	Kosciusko-Whitley	32N	7E-8E	parts of 13, 18, 19
Unnamed	Kosciusko	32N	7E	15 S. E.
Rine	Whitley	32N	8E	19 N. C.
Tadpole	Whitley	32N	8E	19 N. E.
Cedar	Whitley	32N	8E	10-11
Small unnamed Lakes	Whitley	32N	8E	14 S.
	Whitley	32N	8E	10 N. E.
	Whitley	32N	8E	3 W. C.
	Whitley	32N	8E	3 N. W.
	Whitley	32N	8E	2-11
	Whitley	32N	8E	11 N. C.
James	Kosciusko	33N	7E	parts of 8, 9, 17, 16
Webster	Kosciusko	33N	7E	parts of 11, 12, 14, 13
Kaiser	Kosciusko	33N	7E	13 S. E.
Unnamed	Kosciusko	33N	7E	25 N. E.
Black	Kosciusko	33N	7E	12 C.
Unnamed	Kosciusko	33N	7E	13 N. E.
Mill Pond*	Noble	33N	8E	18-19, 17
Baugher	Noble	33N	8E	16 C. E.
Johnson	Noble	33N	8E	16-21
Horseshoe	Noble-Whitley	33N	8E	22-27
Beer's	Whitley	33N	8E	27 E. C.
Brown	Whitley	33N	8E	26 W. C.
Smalley	Noble	33N	8E	parts of 15, 22
Little Metz	Noble	33N	8E	15 C.
Metz	Noble	33N	8E	15 N. C.
Buckle	Noble	33N	8E	10 S. C.
Stump	Noble	33N	8E	10 S. W.
Gilbert	Noble	33N	8E	9-10
Dollar	Whitley	33N	8E	25 S. W.
Loon	Noble-Whitley	33N	8E-9E	parts of 36, 31, 1
Old	Whitley	33N	8E	35-36
New	Whitley	32N	8E	parts of 2, 1
Goose	Whitley	32N	8E	12 S.
Big	Noble	33N	9E	parts of 32, 33
Goose	Noble	33N	9E	29 S. W.
Herriff	Noble	33N	9E	20 C.
Crane	Noble	33N	9E	33 N. E.
Crooked	Noble-Whitley	32N-33N	9E	parts of 33, 34, 4, 3

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[1] Addresses given are the latest on file. If address is known to be incorrect the address is followed by (I).

* Fellow.

† Non-Resident Fellow.

[2] Figures following M, F, and NR indicate date of election to membership, fellowship, and non-resident fellowship respectively.

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Baker, E. G. Stanley, R. F. D. No. 3, Bourbon................ M29
Baker, Lora M., R. R. No. 3, Hartford City................... M20
Baker, Lowell F., Carmel..................................... M28
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Beabout, Reuben, Michigantown............................ M30
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Beebe, Ralph E., 724 Ashland Ave., Muncie.................. M26
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Bishop, George N., Mitchell, Ind............................ M27
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Cravens, Irene E., Bloomfield	M30
Craw, Joe R., Hagerstown	M29
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Crone, John T., Newtown, Ohio	M30
Crouch, Frances E., Hanover	M27
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*Dietz, Harry F., State House, Indianapolis................M09, F22
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Doan, Martha, Iowa Wesleyan College, Mt. Pleasant, Iowa...... M96
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Dolan, Joseph P., Syracuse................................. M95
Dolby, George Paul, R. R. No. 7, Box 36, Huntington........... M31
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Emerson, John D., Ligionier................................ M25
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Furbay, John Harvey, Taylor University, Upland	M31

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Glenn, Gail Geneva, Ramsey	M28
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Greenawalt, Stewart, Madison, Pa.	M24
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Page 67, line 5, read "Fegatella" for "Fugatella".
Page 67, line 20, read "Conocephalus" for "Cenocephalus".
Page 67, line 29, read "as" for "a".
Page 67, line 39, read "complanata" for "Complanata".
Page 68, line 2, read "water-culture jars" for "water culture jars".
Page 68, line 5, read "water-culeure jars" for "water culture jars".
Page 68, line 6, read "water-culture jars" for "water culture jars".
Page 69, line last, read "zü" for "Zu".
Page 70, line 24, read "lid is" for "is lid".
Page 71, line 23, read "californica" for "Californica".
Page 71, line 29, read "Vaccinium" for "Vaccineum".
Page 71, line 32, and following read "per cents" for "percents".
Page 75, line 18, read "Cercis" for "Ceris".
Page 75, line 26, read "profunda" for "rofunda".
Page 75, line 30, read "Ipomoea" for "Impomoea".
Page 77, line 10, read "dichotomiflorum" for "dishotomiflorum".
Page 78, line 14 from the bottom, read "Malva" for "Malvia".
Page 78, line 14, from the bottom, read "Wallw." for "Wallm.".
Page 89, line 30, read "rock substrata" for "rocks ubstrata".
Page 90, line 26, read "Brachythecium" for "Brachytlecium".
Page 91, line 23, read "julaceus" for "julaceous".
Page 91, line 26, read "Wahlenbergii" for "Wahlenbergil".
Page 91, line 44, read "pygmaeum" for "phgmaeum".
Page 93, line 23, read "Polytrichum" for "polytrichum".
Page 93, line 43, read "oxycladon" for "osycladon".
Page 94, line 19, read "Entodon seductrix" for "E. sebuctrix".
Page 94, line 19, read "Brachythecium salebrosum" for "B. salebrosum".
Page 94, line 22, read "C. chrysophyllum" for "C. chrysophllum".
Page 94, line 30, read "Polytrichum spp." for "Polythricum spp.".
Page 95, line 4, read "attenuatus" for "attenuata".
Page 95, line 16, read "Eurhynchium" for "Eurphnchium".
Page 95, line 47, read "Pylaisia" for "pylaisia".
Page 96, line 20, read "Eurhynchium" for "Eurphnchium".
Page 96, line 23, read "Forsstroemia" for "Forrstroemia sp.".
Page 96, line 30, read "Aulacomnium" for "Aulocamnium".
Page 97, line 4, read "Forsstroemia" for "Forrstroemia".
Page 97, line 8, read "Campylium" for "Sampylium".
Page 98, line 26, read "Brachythecium" for "Brachuthecium".
Page 99, line 10, read "Philonotis calcarea" for "Philonotic calcare".
Page 99, line 47, read "argenteum" for "argentuem".
Page 100, line 1, read "pygmaeum" for "phymaeum".
Page 100, line 2, read "curvifolium" for "Curvifolium".
Page 100, line 3, read "molluscum" for "Molluscum".
Page 100, line 17, read "Fissidens" for "Fissidans".

Page 119, line 16, read "P. hybridus" for "p. hybridus".

Page 119, line 23, read "1920. (Specimen is in Deam Herbarium.)" for "1920, (Specimen is in Deam Herbarium)".

Page 119, line 25, read "Carex" for "Cares".

Page 119, line 35, read "Liliaceae: Lilium superbum L." for "Lilaceae: Lilium superbum L".

Page 120, line 11, read "Dumort." for "Dumort".

Page 120, line 16, read "intercursum (Bickn.)" for "intercursum (Rickn.)".

Page 120, line 29, read "crinita" for "crinata".

Page 120, line 32, read "M. spicata L." for "M. spicata L".

Page 120, line 33, read "Anagallis-aquatica" for "anagallis-aguatica".

Page 121, line 7, read "villosissimum" for "cillosissimum".

Page 121, line 7, read "Scribnerianum" for "Scribnerainum".

Page 143, line 9, read "2RMgX" for "3RMgX".

Page 149, line 13, read "40" for "39".

Page 156, line 1, read "HETEROCYCTIC-ALIPATHIC" for "ALIPATHIC-AROMATIC".

Page 238, line 4, read "passing" for "passin".

Page 242, line 26, read "topography" for "topogrphy".

Page 335, line 3, read "stages" for "states".

Page 343, line 38, read "collating" for "collecting".

Page 375, line 5, read "height 23.5 mm".